AutoCarto Six Retrospective

A Commemorative Book Celebrating the
Sixth International Symposium on Automated Cartography,
International Perspectives on Achievements and Challenges

Held October 16-21, 1983
National Capital Region of Canada

Barry Wellar, Editor

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Introduction to the AutoCarto Six Retrospective Project

Over the past 50 years we have seen the emergence of a field which I like to refer to as computational geography. It was authored by many individuals who were attracted to it from various disciplines and fields of interest. These included geographers such as Roger Tomlinson, who gave us the name and original vision of geographic information systems; those doing computer modeling of geographic phenomena like Britt Harris, Duane Marble, and others; those working in cartography like David Bickmore in the UK; Howard Fisher, at Harvard, working with maps for computer graphics and spatial analysis; and Ed Horwood who was interested in urban and regional information systems.

The emergence of the field was not based just on the technologies; it was also a social process. At first dozens, and then later, hundreds and thousands of individuals contributed ideas and, through their respective and collaborative efforts, advanced the design, development, and application of geospatial technologies.

Beginning with the first meeting in 1974, AutoCarto symposia played an important role in bringing together these often very different interests, without regard to their origin or the discipline from which they came. Individuals were encouraged to share and cross-fertilize ideas, technologies, theories, and methods. The papers in *AutoCarto Six Retrospective* are evidence of the continuing enthusiasm that their authors have for both contributing to this field and applying it to their own disciplines.

I myself started as a landscape architecture student, and was attracted to the idea that computer mapping and geographic information and analysis could make a better world. When I started a professional consulting practice I tried to apply this idea to real situations using a very early software tool from the Harvard Lab. I soon recognized the need to develop a technical team that could advance our ability to serve both our customers and a broader community. The resulting organization gradually emerged as important not only for doing our own work, but also as a means of encapsulating the thinking and methods of hundreds of others into a product that became widely known and used in academic, government and commercial settings.

The development of this product depended on our engaging with an ever-increasing community of users and researchers, listening closely to what they wanted us to do, and then creatively engineering and advancing our technology platform in the form of geographic information systems (GIS).

This process of product development moved us through the eras of mainframes, mini computers, work stations, PCs, server environments, the web, and cloud renditions of GIS. With each hardware and infrastructure platform advancement we were able to reincarnate the fundamental principles of using computational geography to advance methods that other people could then realize in the form of fundamental research and applications. It has been an exciting adventure, one which is reflected in the papers in this extraordinary publication.

Over the years, the field which I refer to as computational geography has involved many kinds of participants. There were the academics doing the early research. There were many commercial companies investing in and productizing various aspects of the technology. There were those who experimented with building academic and open-sourced software, and others who commercialized these ideas and built products; I am one of the latter.

Then came early adopters of the technology in various application settings, including those who built urban and regional information systems, and those who described the computational methods for modeling various geographic phenomena.

Many people focused on the measurement of spatial change, using remote sensing and early versions of survey measurements, and ultimately working with advanced GPS, LiDAR, and sensor network measurement systems. Especially in the academic world there were the people who theorized about how to abstract geographic information into ontologies and classification systems for maps.

Others were focused on the representation and presentation of geographic data in the form of cartography and 3-D visualizations. Many participants focused on developing the necessary functional roles within organizations: geospatial managers, GIOs, and professionals such as GISPs responsible for implementing and managing computational methods as workflows that result in greater productivity.

And then there were those who studied the costs and benefits of these early technologies, illustrating savings, efficiencies, better decision making, improved communication, and advances in fundamental understanding.

The diversity of all these individuals and their efforts is an example of true collaboration in science and technology, a collaboration that I believe will continue to make an enormous difference in how we see and understand our world.

The early AutoCarto conferences were events that precipitated hundreds of pioneering contributions. Like raindrops falling on the landscape, they were contributions that grew into streams and rivers of change in our society, ultimately affecting almost everything that we do: how we measure, analyze, predict, plan, design, make decisions, manage, and evaluate our environment.

My good friend Richard Saul Wurman has remarked that, “Understanding precedes action (or at least should).” The contributions of all of the authors in these volumes have, in aggregate form, clearly advanced our understanding of how our world works.

Considering the many challenges that we are currently facing, of climate change, global inequality, shrinking biodiversity, and dozens of other seemingly unresolvable conflicts and issues, we must, at this point in history, apply our best understanding of science, technology and design thinking if we are to survive as a human species and create a more sustainable world.

Like many of my colleagues, I am proud to have contributed to this rapidly changing digital landscape; but I am even prouder to have been part of the amazing community of individuals represented by the authors of papers in *AutoCarto Six Retrospective.*

We owe special thanks to Barry Wellar who organized and edited this Retrospective; it was his vision that has inspired all of us to look back from thirty years later to try to gauge the significance of AutoCarto Six.

Given the rapid changes taking place in today's landscapes, both real and digital, I wonder how what we have done will be appraised by others, perhaps another thirty years from now.

Jack Dangermond, President, Esri

Editor's Foreword

The notion of organizing an event to commemorate the 1983 Autocarto Six Symposium initially arose during discussions about association anniversaries at the 50th conference of the Urban and Regional Information Systems Association (URISA) in Portland in September, 2012.

However, having just put many months into organizing and editing the URISA book, *Foundations of Urban and Regional Information Systems and Geographic Information Systems and Science* (urisa.org), the idea of involvement in another project of that nature held very little appeal. Then, in the true spirit of "It's not over until it's over", by late June of this year I was persuaded that the Autocarto Six Symposium and the proceedings deserved the attention that could accrue from a commemorative event.

Discussions with Fraser Taylor, the AutoCarto Six Conference Chair, revealed that no other commemorative plans were afoot to his knowledge, so the decision was made to proceed with a publication which I titled, *Autocarto Six Retrospective.*

Initially the timeline for producing papers was relatively tight, given that invitations started going out in July which is prime vacation time in much of the world, and because a due date of September 30 was originally set in order to have *AutoCarto Six Retrospective* completed by mid-October.

Upon further consideration, however, with emphasis on accommodating authors who were committed to more pressing tasks, and authors who did not learn about the project until late in the process, it was decided that we would move the due date back a month.

The compelling advice received which led to the deadline extension decision was that, after 30 years, no one was likely to complain about a 30-day slippage in the release date.

Further, the shift in timing provided an opportunity to link the book release to GIS Day on November 20, and any papers still in process can be added to the posted book shortly thereafter.

As a closing note, personal and professional thanks are given to the contributors to *Automated Cartography: International Perspectives on Achievements and Challenges* who "Stayed the course" over the past 30 years, and who generously took time from other obligations and interests to contribute to *AutoCarto Six Retrospective*.

Barry Wellar

Foreword, AutoCarto Six Chairman

In the Foreword to the original AutoCarto Six Proceedings I noted that the Proceedings had a number of unique characteristics. These involved: an international perspective with authors from more nations than any other AutoCarto conference up to that time; a uniquely Canadian flavor with a number of outstanding papers in both English and French; and a unique opportunity for Canadians in particular to take stock of their achievements and to identify new challenges.

The Foreword concluded with the sentence “The Proceedings of AutoCarto Six are the written record of a remarkable collective endeavour.

This publication of *Autocarto Six Retrospective* owes much to the energy and initiative of Dr. Barry Wellar, the Editor of the original Proceedings.

It also shows just how important the AutoCarto Six symposium was. In retrospect, many of the presentations at AutoCarto Six were ground-breaking, and set the directions for many of the key issues in the field of geographic information processing and cartography that we are dealing with today. The technology and the semantics have changed, but many of the concepts and ideas introduced at AutoCarto Six are even more central today than they were in October, 1983.

AutoCarto Six was a truly innovative and important symposium, as many of the original authors show in their contributions to this book, Unfortunately, some of the authors of those early papers are no longer with us, but their ideas and contributions live on through the AutoCarto Six Proceedings.

D. R. Fraser Taylor

Preface

The papers in the Autocarto Six proceedings were grouped as follows:

A. Keynote Sessions

B. Plenary Sessions

a. Digital Integrated Mapping Systems
b. Practical Applications of Computer-Assisted Mapping Systems
c. Computer-Assisted Support for Decision-Making
d. Research and Development in Automated Cartography
e. Appropriate Technology for the Third World

C. General Track Sessions (Volume I)

1. Integrated Systems
2. Practical Applications
3. Problem Analysis/Decision Support Systems
4. Research and Development
5. Education and Training

D. Special Track Sessions (Volume II)

1. Limited Investment Mapping Systems
2. Institutional Mapping Efforts: Status and Prospective
3. Data Structures
4. Mathematical Cartography
5. Problem Analysis: Projects to Processes
6. Thematic Mapping
7. Remote Sensing: Systems and Activities
8. Electronic Distribution/Exchange of Cartographic Data

The same order of topics is used in the layout of *Retrospective*. This approach respects decisions made thirty years ago about core themes and sub-themes in automated cartography, GIS, and related fields.

Moreover, all the headings or variations of them have been used multiple times in publications and conference programs since 1983, so for reasons of genesis, pertinence, and continued currency they provide a highly suitable framework for organizing the order of papers in *AutoCarto Six Retrospective.* And, I believe it fair to say, these topics would warrant consideration as a framework for organizing and perhaps combining papers from other similar, commemorative book projects.

Barry Wellar, Editor

Acknowledgements

The *AutoCarto Six Retrospective* project was the beneficiary of assistance provided by a number of individuals and several organizations.

Thanks are given to the following individuals for their contributions to the production of *AutoCarto Six Retrospective:*

- Sam Herold for providing technical advice and support, and for formatting and compiling the final, digital version of the book;
- Carolyn Weiss, David Blakemore, David Mark, Eric Anderson, Fraser Taylor, Gordon Plunkett, Ian Crain, Nick Chrisman, Bruce Westcott, Barbara George, Eva Siekierska, and Nigel Waters for providing the email addresses or the 'coordinates' for a number of authors;
- Alberta and Cliff Wood for providing the two volumes of the AutoCarto Six proceedings that were used to create the digital versions which are posted on the Wellar Consulting Inc. (www.wellarconsulting.com) and CaGIS (www.cartogis.org) websites;
- Marjorie Wellar for editorial support, and for proofing the papers; and,
- Gordon Plunkett for including a note about the *Retrospective* project in Esri's "Spatial Data Infrastructure Newsletter", and for being a source of counsel to the retrospective project.

Finally, a special word of thanks to the following individuals and organizations whose contributions made production of *AutoCarto Six Retrospective* possible:

- Barry Wellar, Principal, Wellar Consulting Inc. and President, Information Research Board Inc., for undertaking the design and execution of the *AutoCarto Six Retrospective* assignment as a public service;
- Jack Dangermond, President, Esri, Alex Miller, President, Esri Canada, Giulio Maffini, President, a+i2 Inc., Ralph A. Smith (retired), and the Department of Geography and Environmental Studies, Carleton University, for providing financial support to cover the external costs of producing and publishing *AutoCarto Six Retrospective* and related productions.

Barry Wellar, Editor

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Design of the AutoCarto Six Commemorative Project

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ABSTRACT. This paper outlines the reasons for using a retrospective approach to re-visit papers published 30 years ago (1983) in the proceedings of the Sixth International Symposium on Automated Cartography. AutoCarto Six, as it is popularly known, is credited with making numerous, significant contributions to the evolution of automated cartography, geographic information systems, and a number of related fields. In these remarks I discuss how comments by authors on such topics as 'Thoughts shaping the design of the papers', 'Derivative attributions', 'Original contributions', 'Impacts', 'What was new in the papers', and 'What was different in the papers' represent an insightful and instructive way to commemorate AutoCarto Six.

KEYWORDS. Automated cartography, GIS, retrospective method, research design, bench-marking, building blocks, tracking, originality, derivative attributions, design terms of reference, innovation, spatial parameters, spatial sciences, change agents, URISA.

A. Why a return to the AutoCarto Six proceedings?

There are a number of reasons why the decision was made to organize a publication celebrating the 30th anniversary of the Sixth International Symposium on Automated Cartography that was held in the National Capital Region of Canada in 1983. In this paper I present a selection of those reasons, and many more are contained in the retrospectives provided by the authors of papers written 30 years ago which have significantly affected the evolution of automated cartography (AC), geographic information systems (GIS), and numerous related fields (Wellar 2013).

By way of context, as the Director of the Technical Program for AutoCarto Six, and the Proceedings Editor (Wellar 1983), I have re-visited both individual papers and collections of papers for research and practice purposes on many occasions. Moreover, over the past three decades I have had discussions about the papers with their authors as well as with faculty members, individual students and classes of students, private sector consultants and systems developers, and a variety of government officials as well as members of advisory boards and expert panels who are often drawn by agencies and commissions from a mix of disciplines and industries.

The overriding message that I drew from those experiences is that since many of the contributors to AutoCarto Six were pioneers and innovators as well as long-term movers and shakers in the evolution of automated cartography, geographic information systems, and related fields, the re-visit should be designed accordingly. In particular, and among other considerations, it should be regarded as an opportunity to:

- Identify and recognize original and innovative contributions to the literature on automated cartography (AC).
- Identify and recognize original and innovative contributions to the literature on geographic information systems (GIS).
- Identify and recognize original and innovative contributions to the literature on relationships between automated cartography (AC) and geographic information systems (GIS).
- Identify and recognize the magnitude of the international perspectives presented at AutoCarto Six.
- Recall the Symposium focus on achievements and challenges, which took AC, GIS, and related fields into the "Get real, show us what you've got" arena like never before.
- Recall the richness of the AutoCarto Six Symposium program which sought out contributions in such fields or domains as remote sensing, land information systems (LIS), decision support systems (DDS), land registration information systems LRIS), interactive graphics systems (IGS), image processing systems (IPS), municipal information systems (MIS), relational database management systems (RDMS), artificial intelligence (AI), and which also placed great emphasis on papers dealing with data quality issues, the movement from data systems to information systems, and data-information-knowledge transform achievements and challenges.

I believe that realizing any one of those opportunities is sufficient to make a strong argument to re-visit the AutoCarto Six proceedings, and in combination they make a compelling case.

Finally, the Symposium received outstanding support from government agencies, industries, and universities, as well as from hundreds of individuals, and made a significant contribution to the AC and GIS fields, as well as to a number of related fields. Speaking for myself, my colleague Fraser Taylor, and others who enjoyed and benefitted from the AutoCarto Six Symposium, the *Retrospective* publication is one more way to acknowledge that exceptional support.

And, further in that vein, it is one more way to underline the significance of the recent recognition that was accorded to Natural Resources Canada, Statistics Canada, U.S. Bureau of the Census, and U.S. Geological Survey.

In 2012, the four agencies were simultaneously inducted into the GIS Hall of Fame at the URISA GIS-PRO conference. As a contributor to the four nomination statements, I was pleased to write about the many contributions that the professionals from those agencies made over the years to automated cartography, geographic information systems, and numerous related fields, and to the AutoCarto Six Symposium. The *Retrospective* publication is one more opportunity to recall and honour the valuable contributions made by these agencies over the past three decades.

B. Why a retrospective return to AutoCarto Six?

Anniversary events of professional organizations are conventionally designed around temporal milestones at 10, 15, 25, 50, etc., years of activity. Frequently, anniversaries are celebrated by conference proceedings, journal issues, videos, special publications, and books. And, as rule, a relatively small group of people is responsible for whatever is done to celebrate the anniversary.

In the design of a return to the AutoCarto Six Symposium proceedings, we take a very different approach which follows directly from the reasons given in Part 1.

That is, having due regard for the depth and breadth of their expertise and experience, all authors who participated in one of the early conferences that combined automated cartography, geographic information systems, and numerous related fields, were invited to share insights about the thinking behind the papers that they wrote 30 years ago. Or, to re-phrase, the retrospective approach goes directly to the sources themselves and does not presume to interpret, paraphrase, or summarize their thinking.

Two reasons borne of practical experience underscore the benefits of the retrospective *vis-à-vis* the conventional approach to commemorating AutoCarto Six.

First, I have frequently asked the question “What were they thinking?” with regard to policy, planning, program, staffing, development, and other decisions made by municipal councils, federal agencies, businesses, university departments, professional associations, etc. However, it was and is too often the case that the persons responsible for the thinking behind the doing are no longer available, have been removed from office, can’t tell (party policy), can’t remember, etc., so the question “What were they thinking?” does not receive a primary source response.

In the case of AutoCarto Six, a number of the outstanding players in automated cartography, geographic information systems, and numerous related fields contributed papers to the proceedings. It is my sense that any answers which they provide to the question, “What were you thinking?” will be enlightening to say the least.

Second, the conventional approach was used in preparing *Foundations of Urban and Regional Information Systems and Geographic Information Systems and Science* (Wellar 2012), which is a 300-page book with 23 chapters commemorating URISA’s 50th anniversary conference. As the editor of that volume and the author of eight of the chapters, it was frequently my impression that a second volume of a retrospective nature would have added significantly to the account of URISA’s record of achievement.

Finally, authors received an open invitation to comment on the contribution that their papers made to research, education, training, applications, or any other aspect of the evolution of AC, GIS, or any other field of endeavour that they deem to be important to include in the *Retrospective.* The point of this invitation is that the retrospective approach is more experimental than tried-and-true, so it is prudent to provide this esteemed body of contributors room to write about an issue, initiative, situation, etc., as they wish, without being concerned about its 'retrospective' particulars.

C. Terms of reference for authors.

In the absence of a precedent that could be used, it was necessary to design terms of reference to inform authors as to what I had in mind for papers. The terms follow to inform readers of the suggestions made to authors, and in the event that they might be useful for organizers of future retrospective projects.

> Thirty years ago, 110 papers and 50 abstracts were published in *Automated Cartography: International Perspectives on Achievements and Challenges* (Wellar 1983), the proceedings from the Sixth International Symposium on Automated Cartography.
>
> Fortunately, the 1983 conference theme is every bit as relevant in 2013 as it was in 1983. As a result, the achievements and challenges aspects serve as general guidelines for commenting on what was written in the 1983 papers, as well as for commenting on things written in 1983 which are or are not receiving due regard in 2013.
>
> Specifically, we seek comments on the achievements noted in 1983, as well as on whether, when, and how well the challenges noted in 1983 have been met by 2013.
>
> With regard to instructions for paper preparation, they are designed so that the papers can be compiled as submitted (no editing), and will appear professional when posted. The instructions will be sent to authors as we deal with web site matters.
>
> As for the content of papers, I have some thoughts as a result of recent review experiences, and from discussions and communications regarding this specific project. However, my thoughts are just that, and using all, some, or none of them is an author's choice. Or, to re-phrase, while consistency among papers might be desirable, there are other venues for which that demanding level of performance is more suitable.
>
> Current thoughts are as follows.
>
> 1. A considerable amount of effort went into obtaining high-quality papers for inclusion in the proceedings which have received high praise over the years. At a general level I believe we are duty-bound to produce a publication that does justice to what was achieved with the 1983 AC conference, and which reflects

the deep thinking by individuals who made a number of significant contributions to the field 30 years ago.

2. Identify original ideas, concepts, procedures, methods, techniques, tests, approaches, etc., that were introduced into the literature in the 1983 papers.

3. Identify derivative ideas, concepts, procedures, methods, techniques, tests, approaches, and so on that were used in the 1983 papers.

4. Identify derivative ideas, concepts, procedures, methods, techniques, tests, approaches, and so on that were introduced into the literature in the 1983 papers.

Please note the fundamental difference between 3 and 4; that is, someone else's derivatives are discussed in 3, and your derivatives are introduced in 4.

5. We are not repeating, overviewing or summarizing the original papers; rather, we are giving good reasons for those papers to be read, with emphasis on alerting readers such as thesis and dissertation candidates and supervisors, and research proposal writers and evaluators who might benefit from a reminder or direction about the possible, probable, or known origins and originators of current ideas, notions, etc.

That said, several paragraphs of context may be appropriate.

6. Contributors to the retrospective project are long-time participants in AC, GIS, and related fields, and are eminently qualified to offer opinions about matters presented at AC Six that deserve wider attention and increased regard. Again, we are not writing a book requiring all kinds of documentation, although future papers could be turned in that direction.

7. I have completed a draft of my retrospective paper on the keynote I gave, and the headings that I use are as follows:

A. Title of AutoCarto Six paper. Achievements and Challenges in the Field of Automated Cartography: Their Societal Significance

B. Reason for paper?

C. Thoughts shaping the design of the paper?

D. Derivative attributions?

E. Original contributions?

F. Impacts?

G. What was new in the paper?

H. What was different in the paper?

I. Conclusions/Findings/Next Steps.

J. References.

The draft is available to contributing authors upon request.

Again, the terms of reference are suggestions in recognition that some papers may not totally fit this 'template', and therefore need to be designed accordingly.

D. Technical Program Director and Proceedings Editor comments.

No doubt it would be highly instructive and rewarding to adapt the terms of reference and replace the word "paper" by the word "proceedings", as follows:

> Thoughts shaping the design of the proceedings. Derivative attributions. Original contributions. Impacts. What was new in the proceedings? What was different in the proceedings? Conclusions/Findings/Next Steps.

Fortunately, a task of that nature is beyond the scope of this project, and must be set aside for someone else, and/or another day.

What can be done, however, is to present several observations which overview what was involved in hosting the symposium, designing and organizing the technical program, and producing the proceedings.

1. The potential for AutoCarto Six being a "bust" was initially cause for some concern, given that it was the first such conference held outside the U.S., and because of the high levels of skill and resources that had been brought to bear at previous AC conferences. As it turned out, the concern was unfounded, in part because our U.S. and offshore counterparts were very supportive. However, a larger factor, I believe, is that the conference organizers saw the conference as an opportunity to make major statements about both "Achievements" and "Challenges", and made the necessary effort to succeed at the highest level.

2. The symposium theme of achievements and challenges, with its focus on identifying and documenting what was known and done, and needed to be known and done, has been repeated on numerous occasions at other conferences, and is alive and well as of this writing. As we discovered during the lead-in to and execution of AutoCarto Six, achievements and challenges are concepts that are equally applicable to academe, business, and government, and are the basis of mutually beneficial exchanges of points and counterpoints.

3. The quantum jump in the proportion of papers discussing automated cartography in conjunction, association, combination, etc., with geographic information systems brought a major new dimension to the AutoCarto series. I believe it is fair to say that papers in the 1983 proceedings are due explicit attribution for their contributions to numerous government, academic, and business initiatives that resulted from presentations at AutoCarto Six.

4. The general track sessions in volume 1, Integrated Systems, Practical Applications, Problem Analysis/Decision Support Systems, Research and Development, and Education and Training have had an exceedingly good run, from 1983 to 2013 and counting, in a number of venues sponsored by a mix of academic, professional, and technical organizations, as well as in journals and books.

5. AutoCarto Six was perceived as Canada's most significant venture onto the world stage of automated cartography, geographic information systems, and related fields as of 1983. It appears fair to say that Canada's researchers and practitioners from academe, government, and industry were equal to the task at that time, and have maintained a noteworthy presence over the subsequent three decades.

6. AutoCarto Six was Canada's first attempt at involving academics, government representatives, and members of the business community in all aspects of hosting, designing, organizing, and documenting an international conference on automated cartography accompanied by a large proportion of papers with a GIS aspect. Thirty years later, AutoCarto Six is regarded as a role model for similar projects.

7. Prior to AutoCarto Six, Canada did not have a well-connected automated cartography and geographic information system community. The conference was a 'game-changer', and was the basis for creating a critical mass of individuals, agencies, departments, and firms that related to one or more of the general session topics (Integrated Systems, Practical Applications, Problem Analysis/Decision Support Systems, Research and Development, and Education and Training).

Thirty years later, many members of the initial critical mass are still connecting, and are still contributing to the field. A case in point is the widespread support given to the *Retrospective* project.

8. It was stressed throughout Steering Committee and Technical Program Committee meetings that each of the academic, business, and government communities had a key role to play in designing, developing, implementing, and otherwise promoting the Symposium. Organizers from various disciplines have subsequently 'discovered' the academe-business-government model of participation and engagement that was a fundamental feature of AutoCarto Six.

9. Collegiality in combination with skill and motivation were at the heart of a successful AutoCarto Six Symposium. Long story short, 160 papers and abstracts covering more than 1100 pages were processed and published in two volumes that were available at the conference.

And, I hasten to add, and perhaps giving a whole new meaning to the words 'challenges' and 'achievements', that was done in the pre-Internet, snail mail, paper era. Clearly, a high-level performance of that nature can only be accomplished by many people, agencies, departments, and firms sharing in the heavy lifting, and an important part of the AutoCarto Six legacy is the collegiality factor.

Thirty years later that collegiality again came to the fore. The response to requests for assistance in locating authors of Proceedings papers was excellent and, most important for future reference, we have been able to compile a list of email addresses that is a very valuable by-product of the *Retrospective* project.

E. Conclusion.

This retrospective on AutoCarto Six is the first anniversary-type consideration accorded to any Symposium in the AutoCarto series. Based on the enthusiastic and action-oriented response to this venture, I strongly urge that thought be given to similar retrospectives for other Symposia, as well as to anniversary celebrations of the conventional kind.

Finally, as my closing remark, I want to direct readers to the papers prepared by highly-credentialed authors who undertook a somewhat experimental journey back in time to re-visit papers written 30 years ago.

I believe that individually and collectively the papers make a significant contribution to the literature on automated cartography, geographic information systems, and related fields, and to many aspects of the concepts, principles, practices, and research methods and techniques underlying the data-information-knowledge transform process.

F. References.

Wellar, Barry. ed. 1983. *Automated Cartography: International Perspectives on Achievements and Challenges.* Proceedings of the Sixth International Symposium on Automated Cartography, Volumes I and II. Ottawa: The Steering Committee for the Sixth International Symposium on Automated Cartography. The proceedings have recently been scanned, and may be viewed at www.wellar.ca/wellarconsulting/ and www.mapcontext.com/autocarto/proceedings/TOC.html.

Wellar, Barry. ed. 2012. *Foundations of Urban and Regional Information Systems and Geographic Information Systems and Science.* Urban and Regional Information Systems Association. www.urisa.org/files/Foundations_FINAL2.pdf.

Part I

KEYNOTE AND PLENARY SESSION RETROSPECTIVE PAPERS

2

Early Thoughts about Automated Mapping in an Information Society

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Abstract. The AutoCarto Six Symposium in 1983 took place during a time when both the field of automated cartography and the emerging Information Society were in the "take-off" mode. The purpose of the keynote address was to encourage the automated cartography community to think and act in ways that explicitly took into account the information interests of society and, conversely, to sow seeds which would encourage society – institutions, organizations, corporations, and citizens – to be open and receptive to the ways that automated cartography could contribute to both their known and their potential information needs. In this retrospective paper I outline the thinking behind the keynote, identify original and derivative ideas in the paper, and discuss some of the known and possible impacts of the presentation.

Keywords. Automated cartography, GIS, Information Society, Masuda, mass media, public interest, public participation, computer-communications, monitoring, alternative futures, retrospective approach, linkages, geospatial aspect, information needs..

A. Title of AutoCarto Six paper.

Achievements and challenges in the field of automated cartography: Their societal significance.

B. Reason for paper.

It was agreed that the opening keynotes would address the societal and scientific implications, respectively, of the AutoCarto series. Jack Dangermond and I may have tossed a coin to decide who did what for the keynote presentations, but the upshot was that I would do the societal component and Jack would do the scientific.

C. Thoughts shaping the design of the paper.

By 1983 I had been active in community affairs for a dozen years, had completed a 7-year term (1972-1979) at the federal Ministry of State for Urban Affairs (senior research officer; urban information theme coordinator; chief, urban management; assistant director of information technology, director of non-metropolitan development; and, senior policy adviser), and had been a faculty member at Kansas (1969-1972) in Geography, the Institute for Social and Environmental Studies, and the Space Tech Lab and then (1979-and counting) at the University of Ottawa in Geography and Environmental Studies, and the School of Urban and Regional Planning.

Those experiences shared a valuable message. That is, they informed me that an excellent way for professional and technical groups to author their own irrelevance, or to earn the label of inhabitants of “ivory tower havens”, is to talk among themselves about the importance, significance, etc., of what they are doing, and to downgrade, ignore, or give short shrift to the interests of those who pay the bills (taxpayers), or those who hire them to put their skills to work in serving the needs of government, business, universities, and other employers, clients, and users of the products of those skills, including the media.

The mission of the keynote paper, therefore, was to encourage the automated cartography community to think and act in ways that explicitly took into account the information interests of society and, conversely, to sow seeds which would encourage society – institutions, organizations, corporations, and citizens – to be open and receptive to the ways that automated cartography could contribute to both their known and their potential information needs.

D. Derivative attribution.

In the 1983 paper I refer to Masuda (1980) as one of the early contributors to the concept of an “Information Society”, so a derivative attribution is appropriate. With a qualification. That is, while Masuda mentioned images, remote sensing, and satellite platforms, it appears that his perception of information was primarily if not exclusively text-based, and did not extend to cartographic productions, automated or otherwise, as means of representing, storing, processing, or disseminating information.

As for the proceedings from prior AutoCarto conferences, they contain mentions of the utility of automated cartography systems, processes, and products to governments, and to a lesser degree businesses, universities, and research institutes.

However, I had not located any mentions that were of a big picture or societal nature with a clear focus on people. Consequently, although elements of the 1983 paper are derivative in minor or incidental ways, no person, agency, publication, etc., from the autocarto community comes to mind for attribution purposes as a precursor or precedent providing substantive ideas, concepts, procedures, methods, techniques, tests, approaches, etc., for the 1983 keynote.

E. Original contributions.

There are several features of the paper which appear to have been original contributions to the AutoCarto literature. In the event that I have erred in my thinking, I invite having any oversight brought to my attention.

1. Setting aside technical and technological considerations, and explicitly putting societal significance at center stage. My experiences outlined in the section B, Thoughts shaping the design of the paper, and my association with the Urban and Regional Information Systems Association (URISA) since the 1960s, were behind the decision to take a breather from technical and technological bells and whistles, and break new keynote ground at an AutoCarto conference.

2. Explicitly casting automated cartography as a means of informing the public in an Information Society context. Much of the world was affected by the emergence of a computer-communications transformation beginning in the 1960s, but by the 1980s the AutoCarto literature had very limited recognition of or regard for the public as a player, or for how automated cartography products and services would be challenged to compete for attention, funds, etc., in an emerging Information Society. The 1983 keynote was a departure from the focus on maps *per se* to the larger matter of regarding society as a consumer or target of information, and computer-generated maps being one means to that end.

This matter was discussed in more detail in a related 1985 paper (Wellar 1985) published in *Cartographica,* so it is not pursued here.

3. Using mentions of automated cartography in the mass media as a basis of assessing its societal significance. In the offices of elected officials, senior government officials, corporate executives, in classrooms of communications-savvy professors, and at meetings of community associations, the focus of attention in the 1960s, 1970s and 1980s was on media stories – people read newspapers, watched television news, and listened to radio reports – and, generally speaking, they did not give a fig about journal papers or conference proceedings.

The mass media was the societal media of the day, and society was tuned into the mass media, and not to techie or techno productions. The keynote attempted to inform and nudge the AC community mindset in that direction.

4. Introducing the young or younger generation into the autocarto equation. Typically, AutoCarto and similar conferences were overwhelmingly populated with very serious, older (40+) attendees from government, business, and universities. However, as the parent of teens, and professor of teens and recent-teens, it was clear to me that the young(er) generation held perceptions which were very different from those of their parents, or adults in general for that matter.

In particular, for the young(er) members of society tech stuff was an instrument of play rather than a tool of work, and could be a source of fun in both education and entertainment. Including that kind of thinking in an AutoCarto keynote was way outside the box in 1983.

Other original contributions include discussing the use of maps in media (print and television) stories, and exploring the use of maps by elected and appointed government officials in media stories about policy, program, planning, and development matters.

F. Impacts.

Brief comments on several kinds of impacts should be sufficient to illustrate the effects of the keynote presentation on the automated cartography and societal significance relationship.

1. Promoting organization cross-overs. At various times AutoCarto attendance lists and URISA membership lists shared many names, including those of at least three presidents of URISA (Bob Aangeenbrug, Barry Wellar, and Ken Dueker) who made presentations at AutoCarto conferences. And, as shown in a number of tables in *Foundations of Urban and Regional Information Systems and Geographic Information Systems and Science* (Wellar 2012) which was published by URISA, many topics that had their origins in the autocarto field were the subject of discussion in URISA proceedings papers, or were developed as URISA workshops. The 1983 keynote promoted the inclusion of automated cartography topics in URISA's agenda, and the participation of URISA members in AutoCarto conferences.

2. Increasing regard and respect for the media factor. The realization that the media had significant influence on the thinking and doing of political parties, governments, businesses, or universities as institutions did not come early or easily to many members of the AC community, and particularly those with a 'scientist-in-the-lab' bent. The1983 keynote was a very early *heads-up* about the importance of the media, and over the intervening years the media factor has increasingly received its due regard.

As three cases in point, the media factor discussed in the 1983 presentation was a requested/suggested topic for inclusion in keynote and plenary presentations at the 1990 GIS/LIS Conference (Wellar 1990), URISA's 30th anniversary conference in 1992 (Wellar 1992), and the 2005 Symposium, Projecting Geography in the Public Domain in Canada, which was organized by the Canadian Association of Geographers, Royal Canadian Geographical Society, and the Canadian Council on Geographic Education (Wellar 2005).

3. Recognition of the value of automated cartography and GIS expertise by interdependent infrastructures and safety and security panels. In 2004 I was appointed to the Selection Committee, Joint Interdependent Infrastructures Research Program (JIIRP), which was co-sponsored by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Public Safety and Emergency Preparedness Canada, and in 2006 I was appointed to the Strategic Projects Selection Panel – Safety and Security, which was sponsored by the Natural Sciences and Engineering Research Council of Canada. I discussed those programs in a previous paper (Wellar 2009), and readers are referred to that document for details.

To summarize these impacts, if the AC field had not broadened and deepened its scope and adopted the much more society-sensitive perspective that was discussed in 1983, then I do not believe that NSERC would have invited me to bring an autocarto and GIS perspective to the deliberations.

Further, there were powerful, competing interests and influences around the tables, including those which invoked the long histories of mainstream disciplines in science and engineering. I believe that my involvement in the Autocarto series, including papers in 1975 and 1980, and then a lead role in the 1983 conference, were instrumental in creating a credibility factor, which in turn was instrumental in receiving acceptance of my positions regarding the utility/advantage/pertinence of automated cartography and GIS to the research proposals under review.

And, I expect, that was just the beginning in Canada, as well as in other jurisdictions with similar infrastructure safety and security concerns.

4. Giving politicians a reason to get in on the action. The presence of an international high-tech conference in Ottawa scored points with elected officials at the federal, provincial, and municipal levels in terms of the old mantras of economic development and jobs.

However, the societal focus of the keynote added another dimension even nearer and dearer to the hearts of politicians; that is, directly connecting with citizens, a.k.a. voters. As members of the autocarto and GIS communities can attest, it has become increasingly easier over the years to attract politicians to conferences which have a pay-off for politicians, and AC Six was an early and significant contributor to the creation of that mindset in both the AC and GIS domains.

5. Prioritizing the public as a market for automated mapping services and products. A thesis of the 1983 paper was that higher regard for the public interest in automated mapping services and products would have a two-fold consequence:

- The public would benefit by gaining increased access to spatial information; And, concomitantly,
- A market would be created for improved offerings by the automated cartography community in academia, business, and government.

Relative to the situation in 1983, the public now has considerably more access to spatial information and the means for accessing spatial information, and there has been a substantial increase in the size of the public market for automated mapping services and products including, for example, GPS installations in motor vehicles.

6. Putting fun into spatial graphics and spatial graphic devices. In the early autocarto days, fun was along the lines of debating raster-vector issues, and exploring or confirming methods and techniques underlying the reality, spatial data, spatial information, spatial knowledge, and applications transform process. In retrospect, pretty grim stuff.

Now, having autocarto-type fun at all ages involves such pastimes or activities as calling up map images of anywhere and everywhere, checking out store locations in places near and far, flipping back and forth between street maps and satellite photographs, creating and disseminating geo-based videos, playing location-based games, participating in geo-cache contests, virtually navigating from point a to point b, c, and/or d before heading out or while en route, etc., etc., all in the name of enjoying a technology that puts a minimum strain on the brain.

And, doubtless, the wave of geo-apps for fun has just begun.

G. What was new in the paper?

The idea of introducing a societal perspective was a major departure from traditional keynote considerations of what automated cartography research, design, development, applications, and so on meant or might mean for academia, business, or government.

The original contributions discussed in Section E identify some of the new concepts, issues, attitudes, initiatives, etc., that were introduced in the keynote paper.

H. What was different in the paper?

In 1973, a year prior to the first AutoCarto Symposium and ten years prior to AutoCarto Six, I was the Urban Information Theme Coordinator, Ministry of State for Urban Affairs, Government of Canada. It had been my experience that building urban data bases for non-trivial research purposes was a tough slog, and quickly and rigorously constructing them for policy, program bending, and planning purposes might best be described as brutal verging on impossible.

An overriding problem, in my experience, was that a text-based approach was unwieldy beyond belief, and few politicians and not all that many bureaucrats had more than a passing grasp of lower-order mathematics or elementary statistics.

Which brings me to Masuda and his Information Society notions, and where we differ. That is, it was my understanding that his linguistic-written-typographical-electronic information approach was the same as the one that I had already found to be operationally deficient in a serious way, to put it mildly.

In the 1983 keynote, therefore, I added the automated mapping dimension.

My objective in proposing a different route was to take advantage of the ability of many people to readily comprehend images such as maps and photographs of cities, river systems, rural areas, weather phenomena, etc., while struggling to digest lengthy, complex texts, or to fathom pages of formulas, equations, expressions, numbers, and other mathematical or statistical representations.

I. Conclusions/Findings/Next Steps.

Several wrap-up comments arise from completing the retrospective paper examining my 1983 keynote address.

First, this is my initial experience with writing a retrospective paper on a conference presentation, and at a personal level I found it to be an instructive exercise. I believe that formal discussions about the design of retrospectives could be very useful for CaGIS and other organizations.

Second, at a professional level I have become increasingly concerned about the seeming increase in attribution failures among politicians, journalists, and association or organization leaders, as well as among academics (faculty and students), government officials, and members of the business community.

The attribution term of reference for contributors to the retrospective production provided an opportunity to test drive the idea of including such a section in my own future papers, and to look for it or its equivalent in Master's and PhD proposals, research proposals to business and government, position papers of interest groups, government green, blue, and white papers, politicians' pronouncements, and so on.

Third, CaGIS and other organizations have created from a dozen to many dozens of conference proceedings that are frequently put on the shelf until they are re-visited (re-skimmed, more likely) in anniversary publications that cover 10, 20, 30 or more years in one fell swoop.

Having participated in a number of anniversary reviews over the years, I believe that the retrospective approach has more to offer than is generally recognized, and especially if it is done in a selective manner.

Finally, I am only too eager to state that there is much more to say on this important topic than I have said in the keynote, in interim papers, and in the retrospective combined, and that I welcome being apprised of related research proposals, thesis statements, class projects, publications, and conference sessions.

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3

The Evolution of an Operational GIS

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ABSTRACT: The 1983 AC-6 paper reflected on some general trends observed in the evolution through time of information systems, in many application areas. Systems began as collections or inventories of data concerning entities with very simple retrieval requirements, expanding to uses that required analysis of the data, and, eventually, when the potential was realized, to the use of the data to manage a function or resource. Parallels applicable to GIS were seen in the more commonly documented Management Information Systems. This retrospective look at the paper and its impact notes the general applicability of the conceptual model over the 30 years, particularly for urban management applications of GIS. It despairs, on the other hand, with the continued apparent lack of understanding of the need to separate output depiction on maps from the spatial database that should support spatial decision support systems – the natural evolution from automated cartography through GIS to SDSS.

KEYWORDS: GIS, systems evolution, land management.

A. Title of AutoCarto Six paper.

From land inventory to land management – The evolution of an operational GIS.

B. Reason for paper.

At the time of AC-6 (1983), automated cartography (AC) and geographic information systems (GIS) were seen as rather separate realms: the former concerned with automating the manual process of making maps (from drafting through to printing and distribution of the paper products), and GIS concerned with collecting and storing map data (i.e. "spatial data", although the term was not used then) in digital form on particular themes, such as census, forestry, land use, soils, infrastructure, etc., in order to explore relationships between resources and socio-economic observations. For AC, the objective was cost-effectiveness of preparing printed maps, and especially the key capacity to easily incorporate updates and corrections for national and regional mapping programs. For GIS, multiple map production was secondary to statistical summaries and map graphics to support project-specific planning and decision making. The key technical capacity was "overlay" in order to quantitatively relate one mapped theme to another, for example farm incomes to climate and soil quality.

The AC-6 conference was one of the first to encourage the integration of these two solitudes into the concept, as yet unspoken, of the spatial information system.

This paper was prompted, as well, by observing the general lack in the literature of consideration of the conceptual and management aspects of GIS, as opposed to the technical and computational. It seemed that there was plenty written on the concept, design and implementation of management information systems (MIS) in all their manifestations – personnel information systems, financial information systems, marketing information systems, sales information systems, etc., etc. – but little on GIS, and particularly those in an on-going production or operational environment. So the paper was seen as filling a gap.

It sprang partly from some of my earlier thinking on the conceptual and practical differences of the 'systems analysis' required for developing and building scientific systems vs. business applications, that is, process-driven vs. data-driven. (Crain 1974).

In general, the time seemed right – by then the Canada Geographic Information System (CGIS), running under the administration of the Canada Lands Data System (CLDS), had been in production operation for a decade and was hence a relatively mature system – so there might be something to say that would be useful to help the developers and managers of newer systems prepare for how the future might evolve.

C. Thoughts shaping the paper.

One approach applied to the paper was to make the comparison (and some contrasts) of GIS to the more familiar MIS, where the sequence of evolution was better known and more frequently documented. Another theme was to emphasize that, unlike automated cartography, map production was not the principal output of GIS, but one of a suite of products and capacities that could aid in the analysis and decision-making for subsequent management of a resource or service.

D. Derivative attributions.

The very short reference list to the original paper reflected that we found we were exploring new terrain (or at least we thought so), although the observations on systems progression from simple inventory to information management clearly had parallels in MIS as outlined by Nolan (1979) who identified similar evolutionary stages as "Crises in data processing".

E. Original contributions.

The evolution of the CGIS from inventory through analysis to management was a "stand back and look at the history" observation whose uneven progress was evident in the document files and parallel changes in the technology, software and customer base of the system over the years. Simple enough observations that were general enough – based on the path of some other operational GIS – to propose as a general model. The ideas were visible in the Nolan paper and implied between the lines in some of the MIS system descriptions, but were certainly not evident in the GIS literature.

F. Impacts.

The impact of a single paper on what follows is always hard to judge. The paper was one of those selected for the *Cartographica* issue (vol. 21 nos. 2&3, 1984) and it was in that form, relatively speaking, frequently cited for a few years. With permission it was reproduced some years later in a volume of key papers aimed at forestry management (Dick and Jordan 1990).

I extended the ideas in a few subsequent papers that expanded the ultimate evolutionary stage with the more encompassing term of "decision support" rather than management, and in later years (Crain 1992) used it as a jumping off point for conceptualizing the "GIS of the future" as one in which the Spatial Decision Support Engine was the core that employed one or more Spatial Databases to respond to "where" and "what-if" queries to produce services and products (sometimes maps!) to support decision making. I am aware of one software package that was developed along these lines (actually called "*What-If*"), but has long since disappeared.

This paper and a few others at AC-6 that proposed considerations of the big picture and integration of AC and GIS may indeed have had some influence on subsequent systems design – at least we would like to think so.

G. What was new and different in the paper?

A key difference was the general or generic aspect of the paper. It did not detail the technical specifications of a particular system or propose a new or better algorithm for some GIS process. The characteristics and experience with the CGIS were by way of example to illustrate what was believed to be a general principle, which (perhaps) had not been observed before.

H. Conclusions/Findings/Next Steps.

As mentioned in Section F, it is difficult to assess whether, in the long term, this paper and way of thinking about GIS had a significant impact on the way GIS applications evolved into integrated information systems.

There are perhaps a few examples of GIS that have matured into Spatial Decision Support Systems for on-going corporate functions – managing an inventory of resources, capacity to analyze situations and report, and modelling "what-if" situations in support of business or public administration. Urban management systems seem to be the most common. Many modern cities now manage multiple spatial databases of infrastructure, along with demographics for use in an integrated fashion from infrastructure repair and maintenance, through to urban planning and policy decision-making for transportation, residential and commercial development, public safety and the like.

On the other hand many GIS applications continue to be one-time projects where there is no "system" or intent to maintain (or even retain) the spatial data for subsequent use.

My paper and a number of others at AC-6 attempted, in addition, to advance the convergence of AC and GIS – proposing to separate the data (spatial and non-spatial) from the Information System which may or may not produce maps.

It is questionable to what extent this has been achieved in the 30 years that have passed. I recall in the 1980s working with the AC pioneer, the late Prof David Bickmore, who would frequently disparage systems that held rivers as "wiggly blue lines" – that is, where there was a confusion of the spatial entity (river) and its attributes with the depiction of it in one particular map view.

This blurring of map depiction in an output product with the attributes of the spatial object in the data base continues to this day. The ISO 19000 series of standards for "geographic data" continues to use the cartographic concepts and terminology such as "feature" and "feature coding" rather than “spatial object” and “attributes” – from which various types of analysis can be conducted and multiple output products produced depicting the objects in ways suited to the intended use.

As recently as 2010, while consulting to the North American Commission on Environmental Cooperation, I participated in the North American Environmental Atlas Project designed to provide a seamless base map for the continent to be used for the analysis of trans-border and continental scale environmental issues (prepared by a cooperative effort of the three national mapping agencies).

The initial spatial data coverages included the political boundaries, rivers, lakes, waterways, highways and railways, populated places, etc., with the idea that additional thematic layers could be registered and added to it (such as land use and cover, eco-regions, watersheds, soils, climate – some of which have been made).

I found however that the "spatial database" that supported the Atlas contained only broadly classified features, rather than objects with attributes (see for example CEC, 2010). Rivers were classified into two levels only, as were highways (major and secondary). There was no division of rivers into reaches, no river flow rates or direction of flow. Highways had no information on number of lanes, vehicle capacity, surface, etc., and the simple classification into major or secondary was not harmonized between the countries, so Canada appears to have few major roads beyond the 401.

The Populated Places data classifies cities into five very broad population classes and is not consistent with respect to which of the smaller places is included. It has fallen into the cartographic trap of including some selected small places simply to avoid blank spots on the map. That should be a user depiction choice, not built into the data. It means that the simple calculation of total population in an eco-region, or downwind from a power-station cannot be done. The spatial database (or "map layers") can only be used as a graphic backdrop, but not for analysis, much less resource management or decision-support.

And, as a further sin, there was no system in place to update the data or even to correct visible errors (and there are some – try adding the Populated Places to the map and you will find that Saskatchewan has no capital city), nor is there a central authority or email address to send corrections and new additions.

It was as if this was developed as a pretty poster to put up at an international conference.

How very 19th Century, albeit "automated".

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4

Linking Information Society, Geography, and Decision Support Systems and Services

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ABSTRACT. Geography is a core component of automated mapping, GIS, urban, rural and regional planning, policy-making at all levels of government, and of virtually all aspects of both the natural and built environments. However, in 1983 it was frequently the case that geography or the geo-factor as a policy variable domain was not receiving the regard in practice that it was accorded in principle. The retrospective paper re-visits the original paper and the three frames of reference that were presented as key elements in better understanding and better appreciating the relationships among Information Society, geography, and decision support systems and services.

KEYWORDS. Automated mapping, GIS, Information Society, decision-making, building blocks, relationships, cumulative knowledge, retrospective approach, curiosity-driven research, client-driven research, exploratory research, confirmatory research, geo-factor, decision support systems, spatial parameters, change agents, applied geography, computer-communications networks, critical infrastructure, OECD, USDA.

A. Title of AutoCarto Six paper.

Geographic frames of reference for decision support systems and services in an Information Society.

B. Reason for paper.

The intent of the 1983 presentation was to serve two pragmatic purposes.

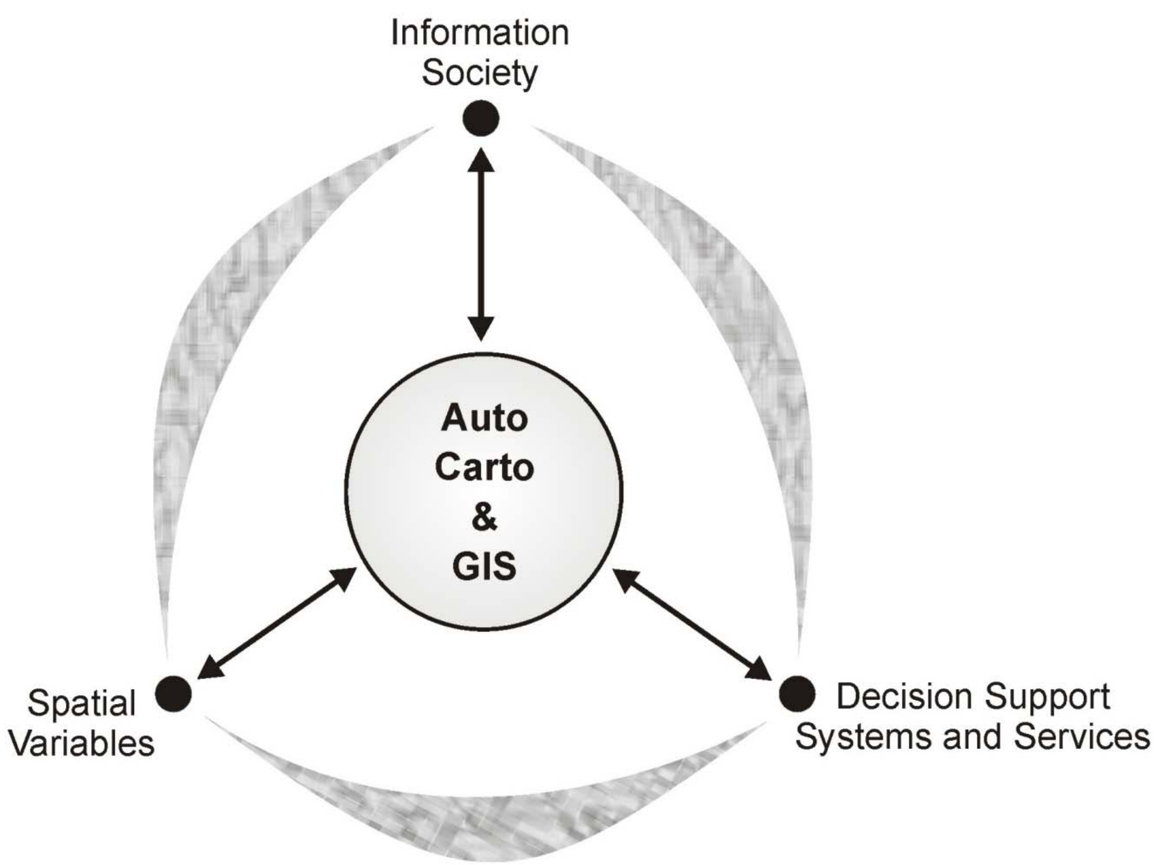
First, in the two years immediately preceding Autocarto Six my major activities included organizing a conference on national and regional economic development strategies (Wellar 1981c), presenting at two conferences of the Australian Urban and Regional Information Systems Association (Wellar 1981a,1983b), chairing the Technical Program, contributing a paper, and editing the proceedings (Wellar 1982b) of the 1982 conference of the Canadian Institute of Planners, presenting and consulting at the International Symposium on Conflict Management in Japan (Wellar 1981b), presenting at a conference on Computerized Cartography and Geographic Information Systems (Wellar 1982a) and writing the impact assessment paper for a special issue of the

Canadian Journal of Regional Science on Public Policy – Urban and Regional Issues (Wellar 1982c)

It was my sense that out of those activities some fundamentals were emerging about relationships involving geography, public policy, decision processes, automated cartography and GIS, and the computer/communications infrastructure of an Information Society.

Figure 1 is a simple graphic depicting aspects of what I had in mind. In brief, it was my concern in 1983 that things which needed to be said were not being said, that there was far more noise than signal in the discourse that was taking place, and that automated cartography and GIS could and should play a critical role in achieving a more robust relationship among Information Society, geography, and decision support systems and services.

Figure 1. Conceptually representing automated cartography and GIS as a hub linking spatial variables, Information Society, and decision support systems and services.



The AutoCarto Six Symposium provided an excellent opportunity to present several of the fundamentals, and obtain feedback from a very highly-credentialed audience.

Second, by 1983 I was involved in a consulting assignment for the Organization for Economic Cooperation and Development to prepare the report, Information for Decision-Making by Rural Authorities (Wellar 1984), and discussions had already begun about organizing an international conference on information systems and services in local governments. By 1985 that discussion culminated in a special track –Comparative International Assessment of Information Systems and Services in Local Governments – at the 1985 URISA conference in Ottawa (Wellar 1985a).

For both projects, the AutoCarto Six Symposium provided an excellent opportunity to pre-test ideas, approaches, topics, etc., by presenting to an expert, international audience, and receiving feedback within days, hours, or minutes for that matter.

As some readers will recall, obtaining short-term turnaround of that nature was a relatively rare treat in the snail mail, pre-Internet days, and was one of the reasons that attendance at conferences was widely regarded as a core part of the education and training function in academe, governments at all levels, and business.

C. Thoughts shaping the design of the 1983 paper?

It had been my general experience in academe, government, and the consulting business that the decision process could be characterized as occurring in stages, such as

- *Awareness, Understanding,* and *Persuasion,* and
- *Identify, Adopt,* and *Implement*.

It was necessary, therefore, to ensure that my remarks were consistent with those mindsets, and to invite suggestions about moving from stage to stage.

Further, as a result of the presentations in 1981 at the International Symposium on Conflict Management (in Kyoto), and discussions with a number of the participants including Walter Isard, Jean Paelinck, Rolf Funck, David Boyce, Peter Nijkamp, and Yeung Lee, as well as with Bill Garrison who was at a transportation conference in Tokyo at the time, a second dominant thought went into the design of the presentation.

That is, since there is the potential if not the likelihood of conflict during any stage of the decision process, the conflict aspect needs to be relaxed if it cannot be precluded. That was done by focusing on the general good, the general societal interest, and inviting a collective approach in elaborating three frames of reference:

1. The essential natures of the geo-factor in the policy, plan, and program domain of both the public and the private sectors;

2. The continuing modification and incrementalism of the technological infrastructure (systems and services) of GIS in an Information society;

3. The changing decision processes and outcomes as a consequence of the "new geography" perceptions of decision participants in an Information Society.

D. Derivative attributions?

By the time of the 1983 AutoCarto Symposium I had read many thousands of pages of text, and I do not recall having read any of the three frames of reference elsewhere. However, there were a number of books that I read multiple times in the years preceding the Symposium, and it is most likely that one or more of Ackoff (1953), Drucker (1970), Highway Research Board (Hemmens 1968), Illich (1973), Masuda (1980), McLuhan (1964), Northrop (1959), and Whitehead (1948) contributed to each frame of reference.

Further, beginning with graduate school days in 1965 and continuing for the next 18 years, I was fortunate to encounter a number of people who not only gave me inputs to each of the three frames of reference, but in fact may have suggested or sparked ideas about one or more of them. In particular, my thinking about geographic frames of reference or the "geo-factor" was strongly influenced by Bill Garrison, Duane Marble, Walter Isard, Leon Moses, and Len Gertler, and the decision support systems and services component by Bob Aangeenbrug, Ed Hearle, Will Steger, Edgar Horwood, Bill Teron, Jean Piggott, David Slater, Marion Dewar, and again, Bill Garrison.

The bottom line is that the frames of reference did not emerge from the ether; rather, they were the by-product of a number of readings and discussions over the previous 18 years, and credit is duly given to those who contributed to my thinking for that presentation in 1983.

E. Original contributions?

As noted above, in 1983 I was engaged as a consultant in a project for the Organization for Economic Cooperation and Development (OECD). Consequently, there was a constraint on publishing material that was in effect proprietary, and had not yet been seen by the client or approved for distribution. The original contributions, therefore, which I believe were introduced to the extant literature via the AutoCarto Six proceedings abstract, are the three frames of reference with their focus on:

1. The essential natures of the geo-factor in the policy, plan, and program domain of both the public and the private sectors;

2. The continuing modification and incrementalism of the technological infrastructure (systems and services) of GIS in an Information Society;

3. The changing decision processes and outcomes as a consequence of the "new geography" perceptions of decision participants in an Information Society.

F. Impacts?

The first, immediate impact is that the paper which resulted from the pre-test at AutoCarto Six was subsequently published by the Economic Research Service and Extension Service, U.S. Department of Agriculture, which hosted the OECD meeting. (Wellar 1984). The published report was subsequently provided to all member OECD countries, and was widely distributed within many of those countries.

The second, immediate impact is that the 1983 presentation played a major role in the success of the track, Comparative International Assessment of Information Systems and Services in Local Governments, at the 1985 URISA conference. That was the first international meeting on information systems in local governments since those held by the OECD in the mid-1970s, and this AutoCarto presentation along others from Canada and abroad was instrumental in obtaining reports for six countries (Australia, Canada, Netherlands, Sweden, United Kingdom, and the United States) for inclusion in a dedicated conference proceedings. (Wellar 1985a).

As for other impacts over the longer haul, several come to mind although no claim is made as to the exact extent or degree that they were influenced by this presentation.

1. Geography and the geo-factor were relatively marginal players in public policy formation at all levels in Canada into the1980s. However, by the 1990s things had begun to change, and by the early part of this decade there was significantly increased regard for geography as a factor affecting policy, plan, and program choices by government and business regarding such matters as sustainability, traffic congestion, land use planning and development, economic development, urban sprawl, urban intensification, fossil fuel production, distribution, and consumption, wind farm locations, landfill locations, shopping centre locations, and so on.

And as for the Canadian public, over the past decade it has become totally plugged into geography, courtesy of The Weather Network and its non-stop application of automated cartography and GIS to bring us graphic representations of weather patterns and climate change phenomena from every region of Canada, and around the world and beyond.

At minimum, there is a coincidence between my promoting regard for geography in 1983, and the ascendancy of geography as a significant policy variable domain for governments at all levels, businesses, and individuals.

2. To my recollection, the only significant, explicit, everyday, and meaningful use of the word infrastructure in Canada prior to the AutoCarto Symposium was in regard to computer/communications infrastructure, which was consistent with Canada's Department of Communications being a recognized world leader in research and development, and applications. However, that terminology in an operational sense pretty much evaporated by the time that the Department of Communications (DOC) was terminated by the federal government in 1996. As a result, Canada continued to get by with terms such as public works, roads, water and sewer, and utilities which, in

retrospect, were apt in the absence of the big picture thinking and doing that DOC brought to the table.

Then, for reasons outside this paper came infrastructure-named initiatives galore, including for example, the creation of Infrastructure Canada in 2002, the striking of the Joint Interdependent Infrastructures Research Program by the Natural Sciences and Engineering Research Council and Public Safety and Emergency Preparedness Canada in 2006, and various infrastructure-based, economic stimulus programs sponsored by federal and provincial governments over the past half-decade.

And, of particular relevance to the 1983 presentation, by 2013 the automated mapping, GIS, and related fields have become a core component of Canada's digital Information systems and services infrastructure.

At minimum, there is a coincidence between my promoting regard for technological infrastructure (systems and services) of GIS in 1983, and its ascendancy as a core component of information systems and services broadly defined in Canada and elsewhere.

3. By 1983 Canada was well into the rural-to-urban transformation that had begun some 30 years previously, and it was not only clear that the relatively easy part was over, but that a long patch of tough sledding was ahead. In particular, the "distance" aspect (Wellar 1985b) was about to undergo dramatic changes, and such geography-related concepts and spatial measures as accessibility, adjacency, compactness, concentration, congestion, connectivity, density, encroachment, intensification, interaction, proximity, region, scale, segregation, sprawl, and spread would be playing a much more significant role in the social, economic, cultural, and political lives of every Canadian.

It is now 2013, and the "where" factor has become a dominant and often sharp-edged feature in Canadian discourse on such significant questions and issues as:

- How to decide where to locate or not locate an LRT line?
- How to decide where to cut or expand rail passenger service?
- How to decide where to put or not put solid waste?
- How to decide where to rezone or not rezone to higher densities?
- How to decide where to obtain or not obtain aggregate for construction?
- How to decide where to locate or not locate fossil-fuel carrying pipelines?
- How to decide where to allow development in the boreal forest?
- How to decide where to locate or not locate half-way houses, gambling casinos, skateboard parks, hockey arenas, wind farms, roundabouts, medical marijuana grow-ops, community traffic zones, or stop signs? And,
- How to decide where to open or close schools, seniors' residences, hospitals, detention centres, libraries, community centres, police stations, or medical clinics?

At minimum, there is a coincidence between my 1983 referral to the "new geography" perceptions of decision participants in an Information Society, and the seeming awareness that, at an increasing rate, geographic considerations are having an increasingly consequential impact on Canadians' social, economic, financial, and political well-being.

However, I do not refer to this as a happy and informed coincidence, given that public awareness of geographic considerations is one thing, and understanding them and doing something pro-active about them is quite something else. Evidence in this regard includes daily media stories reporting on location-related errors that have been made many times before and are in the process of being repeated yet again.

G. What was new in the paper?

I believe that expressing the frames of reference,

> 1. The <u>essential</u> natures of the geo-factor in the policy, plan, and program domain of both the public and the private sectors,
>
> 2. The <u>continuing</u> modification and incrementalism of the technological infrastructure (systems and services) of GIS in an Information Society, and
>
> 3. The <u>changing</u> decision processes and outcomes as a consequence of the "new geography" perceptions of decision participants in an Information Society,

each of which can be used as premises or as the bases of hypotheses was new, as was the call for exploring the relationships between and among them.

H. What was different in the paper?

In previous papers I had used both the curiosity-driven research and client-driven research approaches, but circumstances tended to limit combining both approaches in the same project or paper. However, as outlined in parts B, C, and F, this presentation was an excellent opportunity to combine the two approaches, and materials from the keynote that had been given two days previously were available for use. The keynote is cited in the Anderson Lecture (Wellar 2010) in which I discuss "the significant achievements in applied geography that occur when the principles and practices of curiosity-driven research and client-driven research are combined in specifying and implementing the research statement of problem, the idealized and operational research design, and the criteria and procedures to be used in results evaluation." (http://agsg.binghamton.edu/wellar2005.pdf)

I. Conclusions/Findings/Next Steps.

Writing this paper gave me an opportunity to test the terms of reference prepared for the *Retrospective* design. It is my impression that they are a reasonable first approximation for such an exercise, and that they could effectively cut to the chase in ascertaining the whys and hows behind many of the papers written 30 years ago.

Moreover, there may be other applications of the terms of reference. In terms of pertinence, directness, and brevity, each term reminds me of a question asked by a judge several years ago when I was being qualified as an expert witness:

"What makes you an expert?"

While perhaps not as scythe-like as the judge's approach to getting at the nub of the matter, I believe that these terms of reference are a very effective means of ascertaining the merits of dissertation proposals, research proposals, learned journal submissions, proposed changes to official, general, or comprehensive plans, modifications to manuals, proposed changes to hardware/software configurations, and so on.

And, further along that vein, it occurs that the terms of reference themselves could be a significant by-product of the *Retrospective* project. Specifically, I believe that it would be a very productive exercise to compile and synthesize the comments from other authors about these terms of reference, as well as any suggested terms of reference for retrospectives involving publications, situations, events, and other matters of days past.

Finally, each frame of reference has received attention over the past 30 years, but I believe that much important research – both exploratory and confirmatory – remains to be done with regard to elaborating each frame, and the relationships between and among the frames.

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Part II

GENERAL SESSION RETROSPECTIVE PAPERS

5

Introspective View of Toronto's AutoCarto Six Paper

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ABSTRACT: The purpose of this paper is to look back at what was written for AutoCarto Six about Toronto's surveying, mapping and GIS programs. By 1983, the municipalities in the Metropolitan Toronto area had well established joint control surveying and mapping programs. Metro was just starting computerized mapping and the development of a map data base system including DBMS, CADD and GIS.

When reviewing the paper the following questions were considered. Was the basic intent of the system successfully communicated? It was a multiyear long range program, were the players able to carry forward the original intent? Did political decisions impede the project? What progress was made before AutoCarto Six? What progress was made after AutoCarto Six? What can be done now to promote applications of the system?

KEYWORDS: Toronto, GIS, mapping, surveying, communications, politics.

A. Title of AutoCarto Six paper.

Metropolitan Toronto inter-municipal mapping.

B. Reason for paper.

The intent of the 1983 presentation was twofold. First, to outline what was being done and, second, to document the history of co-operation between local municipalities.

C. Thoughts shaping the design of the paper.

The modernization of surveying and mapping methods and creation of an urban data bank and management system had been on my mind since 1957 when I was appointed Chief Roads Surveyor for Metropolitan Toronto. Describing and communicating my ideas to gain the support of others had been critical.

Metropolitan Toronto was established in 1953 and an Official Plan was drafted showing the major infrastructure projects to be completed by 1980. When I started managing the engineering and right-of-way surveys I found a lack of geodetic bench marks, and no geodetic horizontal control markers for referencing positions. Control surveys started in 1958, in cooperation with Mines and Technical Surveys, Ottawa.

By 1964 work was completed on over 200 new geodetic bench marks, plus 22 first and 472 second order horizontal stations. Since then the control networks are gradually being intensified by adding up to 7,000 bench marks and 15,000 horizontal markers. Simple rectangular coordinates were computed to enable anyone to express or relocate the position of any point relative to the control markers. While the surveying was underway, Metro was developing mainframe computer programs for surveying and engineering design. Since 1965 most maps, plans, surveys and engineering projects have been related to control.

The control systems were designed to be part of a long range program as outlined in papers by Metro Roads to the Government Data Processing User's Group and to Metro Council. The program included first modernizing surveying, mapping, and engineering by using co-ordinates to integrate the data. And, second, building a data bank based on co-ordinates for the storage and retrieval of vast amounts of urban information. The resulting applications of such a system by data mining appear to be endless.

The systems could be built one part at a time, and each part could add to the whole. Each user would get value from his part. But, the value to an individual user is insignificant compared to the value for the overall urban area.

In a 1966 letter to the Metro Chairman, W. Allen, the Commissioner of Roads, G. Grant, stated "In my opinion ... (it) will have a greater effect on the future of the area than all the roads and transit facilities we are presently building." In 1967, Council granted authority to proceed with the program one part at a time. The next important move was to get everyone on side.

The spreading of ideas is generally through personal interaction and engagement. The data flow of ideas is critical when implementing an innovative new system. The more people involved in implementing the system the more likely the ideas will be accepted.

The AutoCarto Six paper mentions some of the organizations, committees, and groups used to communicate the ideas and to move the project forward. The Ontario Chapter of the Urban and Regional Information Systems Association (URISA) was formed about the same time as the AutoCarto paper was written. URISA has been used subsequently to communicate ideas to other data users and municipalities.

D. Derivative attributions.

When starting the Metro system, very few reference works were found that defined a control system fine enough to position and relocate property corners. In addition, there were few papers on the computer design of urban roads. Metro had the first computer system for traffic control, but the engineering programs available were for doing individual computations. The need was for a system that integrated a whole project.

Coordinates could integrate a project. Metro wrote computer programs that allowed individual construction features and right-of-way limits to be staked out for construction directly from control. After construction, the right-of-way boundaries were to be monument from control.

In effect, control marks were to become cadastral survey witness posts. Their physical positions and co-ordinate locations were to be maintained. Metro would continue to own the road and could use the data later.

In the 1950's and early 1960's, there was limited literature regarding urban data banks and geographic information systems (GIS). Most municipal computers were being used for sending out assessment, tax and water statements.

E. Original contributions.

The AutoCarto Six paper was written in 1983 after control surveying and computer design of roads was well underway. Many innovative mainframe computer programs had been written for such tasks as adjusting control networks, property surveying, engineering design of roads and subways, and drafting.

Metro decided against developing its own computer programs for data base management, digital mapping and geographic information management. Rather, in the mid-1980's Oracle (DBMS), Intergraph (CADD), and ArcInfo (GIS) software were acquired. The design of the data base and the development of customized programs for data input were just starting in 1983.

F. Impacts.

Metropolitan Toronto's surveying and GIS programs have influenced surveying and geographic information systems throughout Ontario.

The establishment of the Ontario Coordinate System was a direct result of the Metro programs. Metro staff was engaged to help prepare the conceptual report for the computerization of the Ontario Land Registry System. The reorganization of the Ontario Survey Profession to include branches in Geodesy, Photogrammetry and Geographic Information Management was a result of Metro's system. The start of the Ontario branch of URSIA was influenced by Metro programs.

G. What was new in the paper?

It was clear from the beginning that the GIS project was to be part of an urban information system. That is, data mining type projects for decision making**, and not just for** the mapping and displaying of data themes.

In fact, however, the urban geography part of most projects has been missed, and to date most outputs are beautiful thematic maps.

An alternate method to produce property maps was also mentioned.

In general, prepare and retain an input file for the adjustment of a subdivision plan. To start with, just float the plan into the mapping system. When coordinate values for key points become available, the plan can be adjusted and input into the mapping system.

H. What was different in the paper?

The comment that Central Mapping was moved in 1979 from Roads to the Management Services Department indicates that politics played a bigger hand than was originally expected.

While the programs were in the Transportation Department, many road widening and construction projects were underway. Surveying and mapping were integral parts of these projects. This made project funds available for control markers, and to help fund Metro's contribution towards the base maps. In 1972, when the politicians were closing down the roads programs, the central mapping programs became vulnerable. The Central Mapping Agency's programs were moved into Management Services Department as corporate programs. Unexpected delays had taken place because of political decisions.

Later, in the 1990's City amalgamation was looming and everything slowed down. The political argument for amalgamation was to reduce costs by cutting duplicate programs and by staff consolidation. Managers became reluctant to spend money. Since the new City would not need some positions, for example six city engineers, senior staff started looking for other positions. After amalgamation everything slowed down again. All programs were reviewed, the staffs were reorganized, and the new managers were brought up to speed. Control surveying, aerial mapping and GIS were not standard municipal programs. Some of these programs took years to get final approval to proceed. Again, political decisions impacted the programs.

In the new City after amalgamation, control surveying and mapping became part of Engineering and Construction Services. GIS came under the Information and Technology Centre whose purpose is "... to be a City wide co-ordinating point for driving business improvements ... (to assist) City Divisions in redesigning operations into information technology solutions and to implement those solutions". Even though the GIS programs were moved to the correct division, politics impacted the programs.

I. Conclusion.

This has been a long, slow process, and in some cases the original intent may have been lost along the way. Communicating the core idea and getting municipalities to adopt it has been difficult. It is too easy to cherry pick applications along the way – modernized surveying and mapping methods; improved engineering design and construction methods; cost saving by data sharing; and thematic mapping – and miss the big picture.

As originally noted, the geography applications for municipal management seem endless. URISA has been used to communicate ideas to other municipalities, utility agencies, and conservation authorities. Maybe it is time to establish a URISA Research Board to help guide municipalities into fulfilling the original intent of surveying, mapping and GIS programs.

6

Looking Back at the Feasibility and Prototype of the Product Market Matching (PMM) System for Tourism Planning and Development

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ABSTRACT. In the early 1980s the Canadian Government Office of Tourism commissioned a feasibility study and pilot project to implement a Product Market Matching (PMM) system to help guide national and regional tourism planning, marketing and development. The results of the study by DPA Consulting included a proposed concept for a quadtree-based GIS decision support system. This retrospective paper looks back at the PMM proposal, the technology context, constraints, and the enduring impacts of the ideas presented at that time.

KEYWORDS. Applied geography, tourism, planning, marketing, development, decision support, GIS, quadtrees.

A. Title of the AutoCarto Six paper.

Product and Market Matching System: A computer-assisted approach to tourism planning.

B. Reason for paper.

Our objective was to describe a new decision support system for tourism planning, marketing, and development based on the concept of matching the geographic features of tourism locations to the explicit preferences of tourism market segments.

C. Thoughts shaping the design of the paper.

There were several main thrusts in the paper.

1. To describe the evolving methodology in tourism planning used to analyze and classify the characteristics of places, and match the places to market segments using the market segments preferences for these characteristics. Specifically to:

- Improve target marketing of places and destination areas;
- Determine the gaps, additions and improvements in tourism infrastructure required to increase the attraction of the destination areas to targeted high-profile market segments;
- Provide a user-friendly consumer tool for decision making.

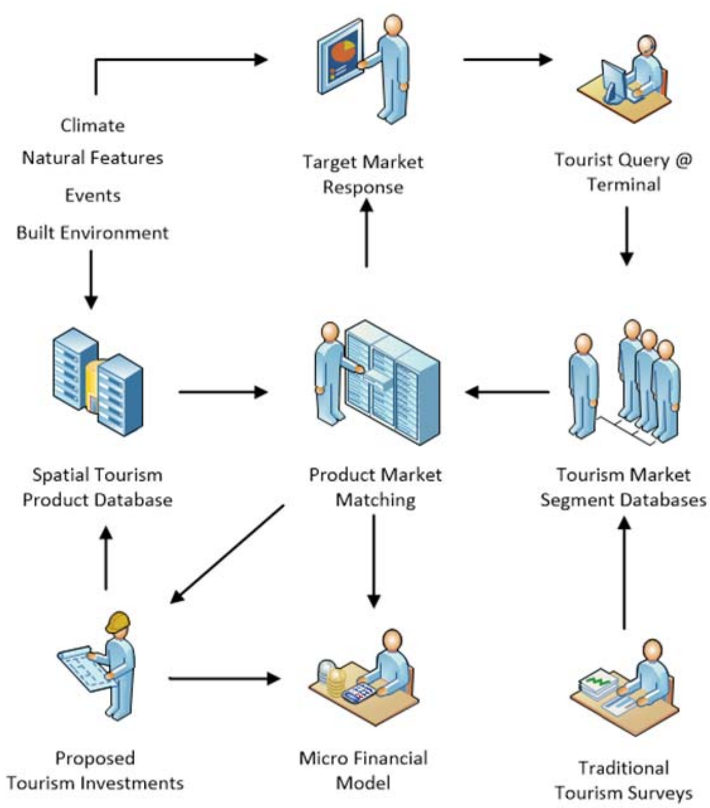
2. To describe a new approach to perform the matching process using a GIS with the geographic data codified in a new (then) quadtree-based framework.

3. A plan to deliver the solution and system (internally) using the newly emerging PC platform and (externally) using the Telidon-based videotext technology.

Federal and provincial tourism agencies had created tourism asset and service inventories. As well, the work of Claire Gunn (1982) had contributed considerably to tourism destination zone mapping. The Canadian Government Office of Tourism (CGOT 1982) and other major tourism agencies had also developed a strong tourism data base of behavioural and socio-economic characteristics and segmentation of tourism markets, including the U.S. market.

The AutoCarto Six paper described the intended plan to develop a new decision support system based on improved data and a quadtree GIS on the newly available PC platform. Figure 1 provides a simple workflow overview chart of the proposed system.

Figure 1. Overview of Product Market Matching System major workflow.



D. Derivative attributions.

The tourism planning work of Dr. Clare Gunn of Texas A&M, the spatial analysis work of Howard Fisher, and the spatial geometry work of Hunter and Samet were the main analytical foundations for the ideas behind the paper.

Their respective contributions are important to our looking back comments, and as a result they are briefly recalled and cited in several subsequent sections.

E. Original contributions.

Bernie Campbell, the client, was Director General, Tourism Development of CGOT, which was then part of Industry Canada. Bernie was the tourism thought leader for the system. Giulio Maffini was the principal of the DPA Consulting team (DPA 1982, 1983) that led the development of the technology and GIS aspects of the feasibility study prototype.

At the time the paper was written:

- The federal government believed that it had a role to play in guiding tourism development to help distribute the economic benefits across the country. Other departments were also involved in contributing to regional development, notably the Department of Regional Economic Expansion (DREE).

- The PMM System was seen as a tool to help make informed decisions across many departments based on verifiable facts, and on a consistent evaluation framework provided by CGOT.

- Basically, the PMM system consisted of two parts; the first was the spatial product market matching component, and the second was a micro marketing system that used the results of the spatial PMM analysis to allocate market share, and determine the feasibility of potential tourism investments.

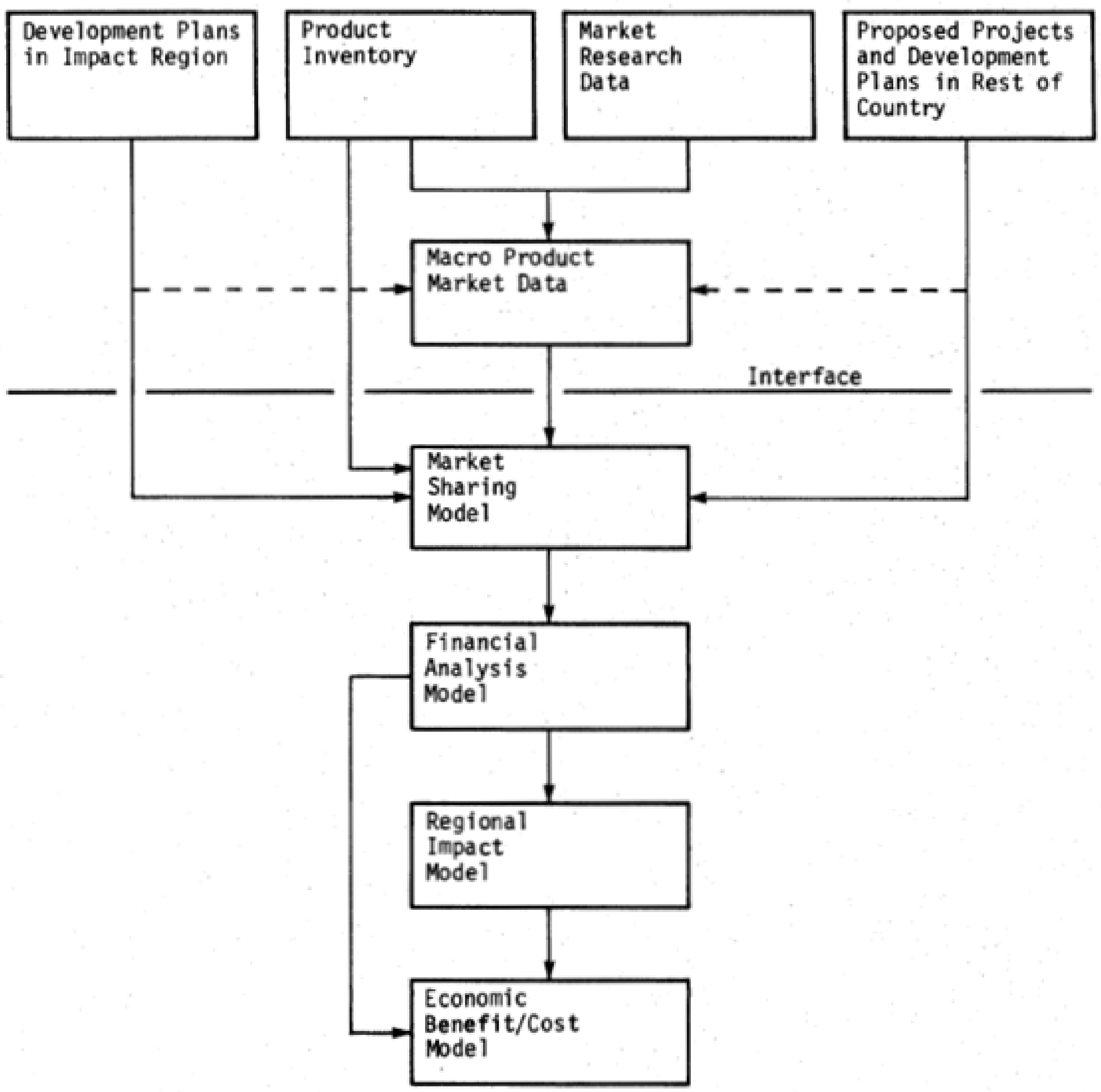
- The idea was that you could perform the PMM analysis with before-and-after tourism investment scenarios, and see if the financial and economic impacts of the investment increased sufficiently to justify the proposed government investment.

- The premise was that, for a target market, if you increase the visibility of a tourism location (through marketing), and the stock of desired tourism product (by development), the attraction of the destination area would increase and, as a consequence, more tourists would travel to it and generate local economic and financial benefits.

- A trial financial model was developed in the prototype to illustrate this functionality, but the connectivity between the two models (spatial and financial) was not implemented.

- Figure 2 shows the logical connection between the macro and micro PMM models.

Figure 2. Relationship between macro and micro PMM models.



- Information about the tourism product was (relative to now) very limited at the time. The feasibility study had been done using 20 spatial layers, including seasonal climate, transport accessibility by road and air, hotels, major events, ski hills, wilderness experience, white-water canoeing and hiking opportunities

- Market data were also somewhat aggregated and limited. The data were based on long established tourism surveys that were not necessarily easily cross referenced to tourism product data. Some examples of the market segments included in the feasibility study were:
    - Pleasure market – U.K. A young couple flying to Canada in the summer and renting a jeep. They want to camp and experience outdoor adventure and sports.
    - Pleasure market – U.S. A middle-aged couple driving to Canada. They will travel in the fall and will require commercial accommodation. The couple is interested in urban and rural attractions and events.
    - Pleasure market – Japan. A group of 40 young people. They will fly to western Canada and transfer to a bus. The group will travel in winter and is interested in urban experience and skiing.
    - Pleasure market – Canada. A family with young children who are willing to drive anywhere in Canada. They will be travelling in summer and are primarily interested in non-urban touring. The family will stay in campgrounds and resorts as well as in hotel/motels.
    - Two other major tourism segments were added (business convention and friends and relatives) for a total of 12 test cases:

Figure 3. PMM prototype test market segments.

	Pleasure Market	Business Convention	Friends and Relatives
U.S.A	1	5	9
U.K	2	6	10
Japan	3	7	11
Canada	4	8	12

For each of these 12 market segments. the CGOT and DPA tourism experts used their knowledge of the available market research data to select and weight the mapping layers most relevant to each market segment. An example of this selection and weighting process is shown for the U.S. Pleasure market. A raster-based (like SYMAP) prototype of the Product Market Matching system had been successfully developed and applied by DPA Consulting for CGOT in 1982. The feasibility study solution was national in scale (Canada), and also included a financial feasibility model for assessing tourism investments. An illustration of the inputs process and resulting matching for the USA pleasure market is shown in Figures.4-6.

Figure 4. Map overlays sequence.

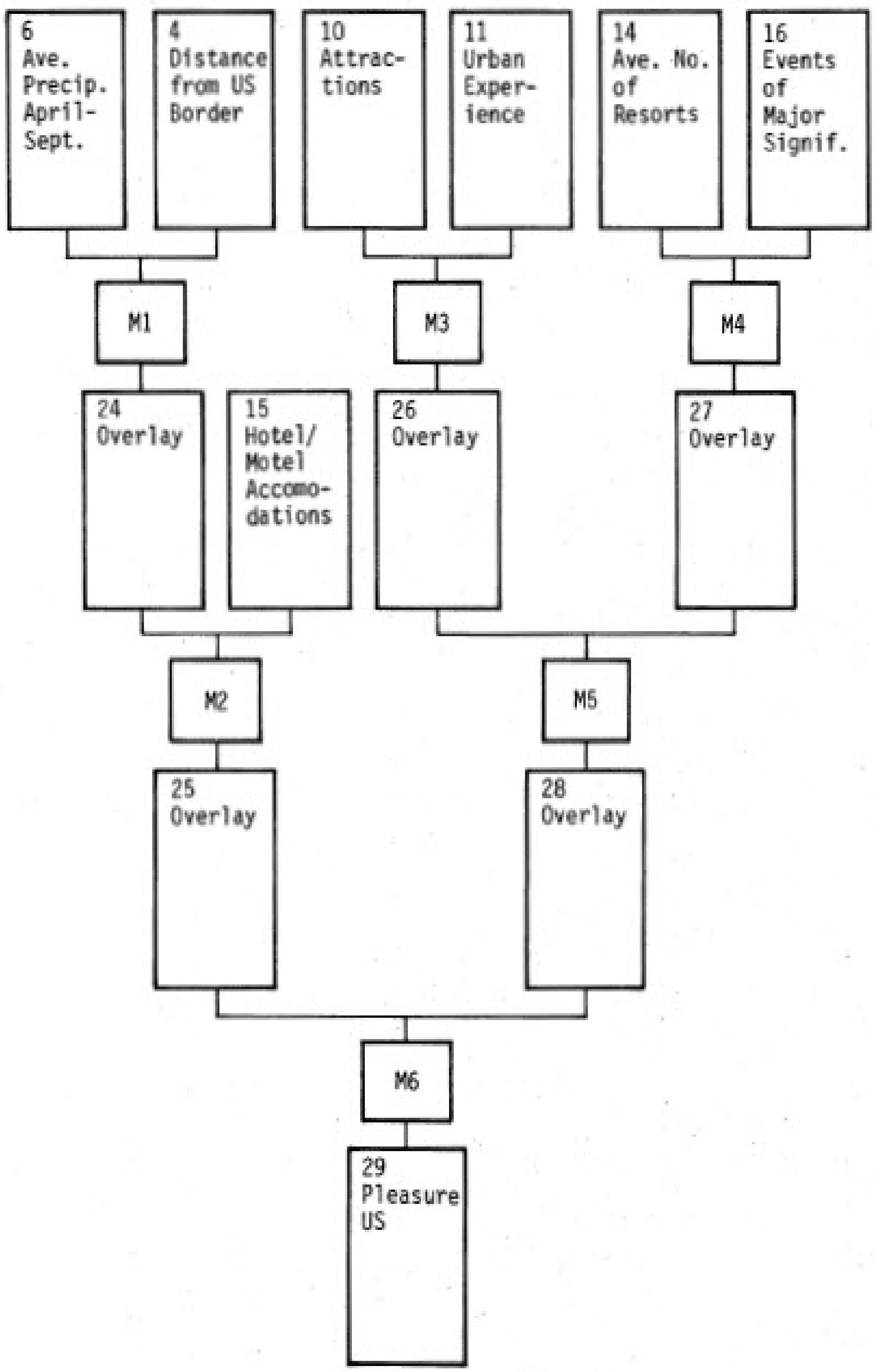


Figure 5. Overlay criteria.

M1

4 / 6		G	A	P
		#	*,+	.
G	*	1	1	2
A	.,0	1	2	3
P	#	2	3	.

M2

24 / 15		G	A	P	U
		1	2	3	.
A	#,W,B Y,0,Z	3	2	1	.
P	+,.	1	.	.	.

M3 M4

10 14 / 11 16		P	A
		.	Other
P	.	.	1
A	Other	1	2

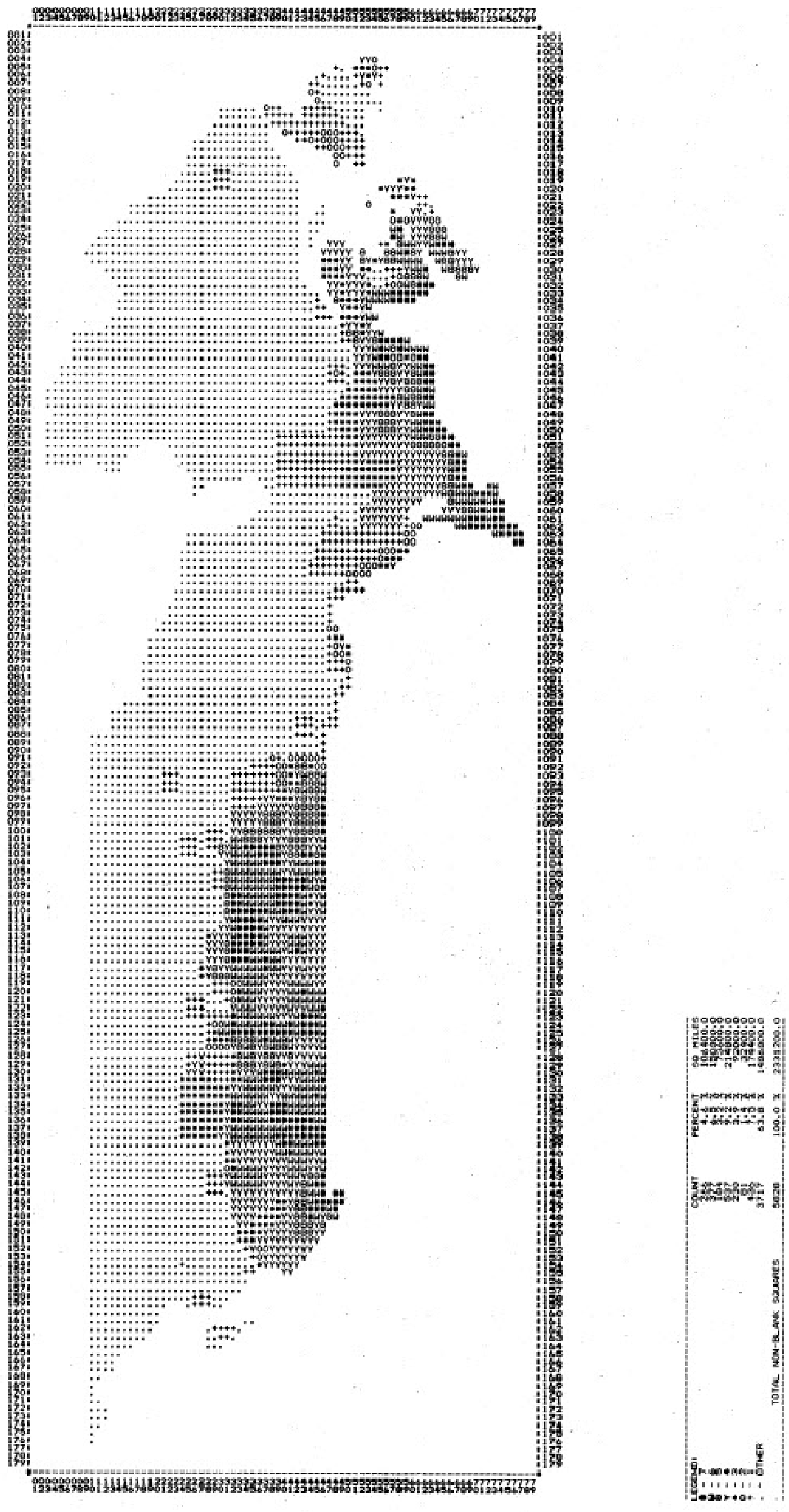
M5

27 / 26		P	A	G
		.	1	2
P	.	.	1	2
A	1	1	2	3
G	2	2	3	4

M6

28 / 25		VG	G	A	P	U
		4	3	2	1	.
VG	3	#	#	#	W	Y
G	2	#	W	B	Y	*
A	1	B	Y	*	Ø	+
P	.	Y	*	Ø	+	.

Figure 6. The resulting matching map for the U.S.A pleasure tourism market.



The product market match feasibility study and prototype clearly demonstrated that it was technically possible to create a mapping system that identified specific tourism **P**roducts or destinations which **M**atched with specific tourism **M**arket segments.

At this point, it is appropriate to recall the technology context in which the PMM project was undertaken.

The original paper allocates a significant amount of space to the hardware and proposed quadtree software technology for the Product Market Matching system. Why was there so much emphasis on this aspect of documentation? To help explain, it is important to understand the state of the emerging technologies at the time. Here are some salient facts about that era.

1. Hardware and operating system software. The paper was written a year after the announcement of the IBM PC. The first PC had only floppy drives for storage of data and programs. It was 1983, the year of the AutoCarto Six paper, that the PC was released with a hard drive. Prior to that time IBM mainframes and mini computers (such as PDP-11 and DEC VAX computers and other long gone computers) were the heavyweight platforms for GIS development.

PC hardware and input peripherals for spatial data (manual digitizers and scanners) were available as were large flatbed plotters, but they were very expensive and were used primarily with mainframes and minicomputers.

Color output was also limited. It was not until 1984 that IBM introduced the enhanced graphics adapter monitor, which was capable of producing 16 colors and had a resolution of 640 by 350.

Up to this time, mapping output was generated through very expensive line plotters, or more economical but crude text printers using double/multiple strikes to create greyscale impressions of thematic data.

Relatively lower-cost color dot matrix printers with a multi-color ribbon were beginning to come on the market. These still relied on multi-strike methods, but with the initial dot density of 60dpi horizontal and 72dpi vertical they could generate “reasonable” facsimile thematic maps. For a 4-color ribbon, each printed line of output required a total of 4 passes. They were typically slow, and noisy.

As standard operating systems for personal computers were just emerging, device drivers did not exist for the PC. Getting spatial data in the computers out to printers, plotters, and color monitors required laborious and tedious hand coding for device drivers.

2. Communications. There was an emerging Internet but no Web. The global, internet user population around the world was very small. All the users fit into a 24 entries per page, thin phonebook. It would be 7 to 8 years later that HTML was invented and, shortly after that, the Web emerged.

The Transmission Control Protocol (TCP) and Internet Protocol (IP) were just introduced in 1983. The Domain Name System (DNS) was created at the end of that year. At the time, there were just a handful of domain servers.

In Canada, the hot communications technology of the day was Telidon, a videotex/teletext service, developed by the Canadian Communications Research Centre (CRC) during the late 1970s and early 1980s. This was a "second generation" version of the videotext systems introduced in Europe in the 1970s. Telidon offered improved performance, 2D color graphics, multi-lingual support, and a number of different interactivity options on different hardware. Telidon-in-the-home is illustrated in Figure 7.

Figure 7. Telidon terminal in the home.

Photograph of J.E. Colbert family using Telidon.
Photo CRC 79-38493.

Although not discussed in detail in the 1983 paper, Telidon terminals were seen as the means by which the Product Market Matching system would be made available to end users at designated locations to make queries and receive customised information displayed back. Another key concept was to use the queries to store the selected preferences in order to build a statistical profile of different target markets.

3. Spatial data. In Canada work had been underway for several years developing the Canada Lands Inventory (CLI). This database was developed for agricultural, forestry, and wildlife management, and could be reinterpreted for tourism-related planning.

Unfortunately the data were stored on mainframes, and at that time were not (for all practical purposes) digitally accessible to those outside government.

At the time, high resolution satellite imagery was only available to the military, and would start to become available for civilian users through the Landsat program several years later.

CGOT had developed several flat file databases of Tourism facilities and infrastructure located and crudely geo-referenced by place name throughout the country.

4. State of spatial encoding and analysis and GIS. Broadly speaking, GIS software development at the time was divided into two streams, raster and vector. In the vector stream, Roger Tomlinson collaborated with IBM in the development of the Canadian Geographic Information System (CGIS), designed around mainframe-based software, to build, organize and publish the Canada Lands Inventory (CLI).

The raster stream had been pioneered earlier (late 1960s and early 1970s) by Howard Fisher in the Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design. The Lab's work led to the creation of seminal software code and systems, such as SYMAP and GRID. This software, while available, was designed for mainframes and large minicomputers and relied on multi-strike text overprinting to generate output.

In Canada, DPA Consulting had developed its own mini- and micro-computer version of a grid-based GIS platform, and used it for their rural, regional and local planning and development consulting projects in Sri Lanka, Bangladesh, and in Canada. The same platform had been used for the CGOT feasibility study and prototype for Product Market Matching.

The description of the potential use of the quadtree method of spatial data encoding (as developed by Hunter 1978; Hunter and Stieglitz 1979a, 1979b; Samet 1980, 1981) and analysis was a significant development decision. The compactness and mathematical elegance of the quadtree approach provided an alternative path for GIS.

Using the quadtree data structure (while still based on raster-like leaves), the limitations of fixed-cell raster databases were overcome. You could have more selective detail with smaller cells in areas where there was more spatial and edge complexity. The quadtree approach competed with the thematic spatial accuracy of vector, and could do so with relatively compact databases and significantly reduced computational geometry complexity.

These features resulted in faster spatial analysis and logical overlay processing on the limited space and processing capacity of the new PC platform (compared to vector and pure raster).

5. User Interface. The PMM system was designed to be completely driven by a set of DOS-like menus on the screen in a sequence controlled by the user. The menus were designed to aid the user in generating the available reports and maps, and the desired map overlays.

This user-friendly approach was leading edge at the time. Microsoft had announced Windows 1.0 in 1983, but it was considered by many as “vaporware” and it did not ship until 1985.

F. Impacts.

The Product Market Matching method in tourism planning has evolved, and continues to be applied at the local/regional scale.

There are an increasing number of instances where GIS has naturally played a key role in implementing the Product Market Matching approach, but government involvement in planning tourism investment and priority setting has declined as an imperative in North America. Tourism planning and development is now more directly led by local governments and the private sector.

The 30 years since publication of the AutoCarto Six PMM paper have seen significant changes in the tourism industry. Market segmentation has advanced due in large part to the Internet, and the ability of market researchers to finely define world markets on the basis of their purchases and Internet search patterns.

The rudimentary segmentation possible in 1983 has given way to a highly sophisticated analysis of tourism markets.

Similarly, tourism product development has evolved to respond to the changing world markets and improved market data.

Technically, today’s developers are able to closely target specific segments, study the competition, and prepare feasibility analysis. Although we continue to see development ‘dreamers’ who think they have the market busting product without resorting to any research, the majority of developments do reflect a high degree of professional research.

Unfortunately, many governments have abandoned efforts to support the industry through product development and destination design research, concentrating instead on marketing support for the industry.

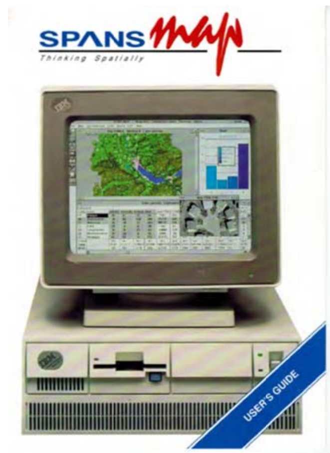
Consequently, although today the industry developers are more sophisticated than ever, creating the master planning focus for development and upgrading still requires higher-level government involvement at the destination and regional level.

There is a role for governments to undertake the kind of effort foreseen by the PMM concept. Given the advances of the Internet, digital technology and improved market research techniques of today, it would be much easier to implement far beyond the concept of the PMM paper submitted for AutoCarto Six.

The Product Market Matching system described in the AutoCarto Six paper was never developed, but it was the inspiration that lead directly to the implementation of a powerful and generic GIS product.

A quadtree-based spatial analysis system for the PC was eventually created and launched in 1984 by a spinoff company of DPA Consulting, called TYDAC Technologies Inc. The product was called SPANS, for **Sp**atial **An**alysis **S**ystem. Figure 8 is a SPANS graphic that many readers may recall.

Figure 8. SPANS, the GIS that emerged from AutoCarto Six.



Within a period of 8 years TYDAC's SPANS was adopted by over 3000 leading researchers from around the world. TYDAC won national awards for innovation, and the SPANS software was recognized internationally as a powerful and practical GIS modeling PC platform. The technology was eventually acquired by PCI Geomatics, another Canadian company and a world leader in geo-imaging products and solutions.

The individuals who originally led the development and use of the SPANS technology have become a diaspora of industry and technology thought leaders in the geomatics and related industries. Individuals who led TYDAC and developed SPANS, and who have had significant scientific and business impacts in the technology world in Canada and overseas include:

- **Wolfgang Bitterlich,** the key mathematical genius behind SPANS who adapted the quadtree geometry theory to a PC-based platform. Wolfgang continued to innovate and later joined ESRI (sadly, Wolf passed away this past year);
- **Terry Moloney,** President and CEO of PCI Geomatics;
- **Louis Burry,** Vice-President of Technology and Delivery at PCI Geomatics;
- **Geoff Zeiss,** software developer, author, GIS evangelist and thought leader who publishes *Between the Poles*;
- **Mike Comeau,** the exceptional GIS practitioner who has been instrumental in the dissemination of geomatics technology in Canada and throughout the developing world. Mike is also the key volunteer and virtual

custodian who liberated the Canada Land Inventory (CLI) database that he helped to create;

- **Joe Francica,** editor-in-chief and vice-publisher of *Directions Media*, the leading online news channel for location technology;
- **Flavio Hendry,** CEO of TYDAC Inc. – who kept the TYDAC name alive in Switzerland and Europe and continues the passion for quality GIS analysis and illuminating GIS presentation;
- **Mike Arno,** co-founder and CEO of Superna, a leading data center and cloud computing certification and software company;
- **Doron Nussbaum** – Associate professor of Computer Science at Carleton University doing leading research work in computational geometry and geographic information systems.

Richard Higgins and **Giulio Maffini,** the founders of TYDAC, and a number of other key TYDAC staff went on to lead the development and dissemination of the VISION* enterprise GIS technology at MCI Systemhouse. This was another innovative Canadian product that was the first to use an open embedded RDBMS (Oracle) and quadtree indexing schemas for very large complex vector databases of outside plant in cities, utilities and telecom companies. VISION* technology was originally developed by GeoVision, a sister company of TYDAC, which was led by another GIS luminary, **Doug Seaborne**.

In addition there were literally hundreds of innovative researchers in government, industry and academia who applied the SPANS quadtree system in virtually every discipline. This included urban and regional planning, commercial and retail market analysis, geology and mining, agriculture, fisheries resource management, coastal management, national boundary disputes, environmental impact, and defence and Intelligence simulation.

G. What was new in the paper?

The tourism topic and the spatial quadtree method described in the paper were new concepts that had not come together before. The concept of systematically describing and geographically assessing the landscape of Canada by the preferences of tourism segments was certainly new. Transforming tourism market research data into spatial criteria was new. Doing so with new emerging PC technology that could be maintained and operated in an office environment was new. The concept of making such a solution available to end users before the Web (using Telidon) was really new. But in those early days of personal computers and communications, everything then was new.

H. What was different in the paper?

The paper was an amalgam of innovative concepts that were not traditionally presented together. Typically, technical papers maintained much more rigid boundaries. Tourism, mathematics, GIS, communication and hardware technology would normally be treated in separate papers in separate journals. This paper was the first instance that we are aware of in which GIS technology was applied to tourism market and product analysis and matching combined with financial and economic analysis. The intended use of Telidon to service end tourist users and present the matching results was also different, as was building a market database with the use of the Telidon queries and preferences to connect market choices to the available, whole tourism product. The eventual emergence of the Web 7-8 years later made servicing end users a lot more practical but, at the time, our approach was certainly different from traditional efforts.

I. Conclusions/ Findings/ Next Steps.

The feasibility study and prototype work described in the paper demonstrated that the system could be developed and used for effective tourism development planning, and had the potential to be used as a consumer marketing tool. Although the PMM prototype technically worked well, there were several issues:

1. Operational applicability at the national level. To be fully operational on a national level, PMM required comparable digitized quantitative data on assets and services from 12 provinces and territories. This database was not available in 1983.

2. Qualitative data. In 1983 Canada had little qualitative data (star rankings, quality assessments, etc.). These data were essential for comprehensive PMM functionality.

3. Market data. Although excellent consumer demographic and segmentation data were available on the U.S. market, similar data on the domestic Canadian and overseas markets were not available.

4. Cost. Although the cost of the technology was modest, the cost of collecting, digitizing, and mapping the product data was beyond the budgets of the CGOT.

The product/market matching capacity in Tourism Canada to produce a tool for national, provincial/ territorial, destination and private sector planning, and the possibility of rolling this capability out as a consumer information system in 1983, were not economically feasible with the existing information base, computer capacity, and pre-Internet computer-communications circumstances.

During the 1990s, Tourism Canada and several provincial agencies were converted into crown corporations or quasi-private sector operations, and the product development operations were abandoned. Thus, the incentive for government to work closely with public and private sector entities in developing new, and improving existing tourism products, diminished.

Although the project as envisioned in the AutoCarto Six paper did not come to fruition, the concept did live on. Some Canadian examples can be found in many of the strategy documents which led to Federal/Provincial Tourism Sub-Agreements (totalling over $250 million) supporting tourism product and destination upgrading across Canada.

As Director General of Development with Tourism Canada from 1983-87, Bernie Campbell was deeply involved in the strategic and implementation aspects of these deliberations. The experience and learning leading up to the PMM prototype, and production of the AutoCarto symposium paper, heavily influenced the approach to the strategic plans and implementation of the Sub-Agreements.

Later, while Campbell served as Deputy Minister in Alberta, Alberta Tourism initiated a programme designed to support communities in their development and implementation of Community Tourism Action Plans. The product/market match strategy was again used to guide development of these plans throughout Alberta.

Campbell also had the opportunity to participate in an analysis of tourism products/destination zones and preparation of development strategies in Jordan, Lithuania, the north west of Ukraine, and the southern Philippines.

In each instance he was able to utilize the product/market match method, manually preparing an inventory of destinations and products, mapping same, and cross-referencing this information with available key market data and profiles. This method provided a match of existing products with existing markets, and allowed for an analysis of destinations to determine what product additions and/or upgrades were required to better meet market demand.

Response by the client to this strategy was very positive. The Jordan development strategy was subsequently funded by USAID. In the other cases, elements of the development strategies were funded by municipal or regional governments, and trade associations along with the private sector.

The concepts of product market matching described in the paper are still relevant today, and embraced by tourism planners for smaller regional destination areas. The potential for a significantly improved product market matching system as described in the AutoCarto Six paper using today's technology is now readily achievable.

The geographic mapping data and the geo-referenced data and public and private tourism infrastructure inventories are accessible through the web via search engines. For the individual users, it can be argued that a pretty good product market matching system is generically available now through the existing Web search query tools, mapping applications, and the enormous quantity of very detailed product descriptions placed on the Web. This is not just available for Canada, but for the whole world.

Satellite, GPS, address, photos and videos, 3D and street level viewing Web applications now also provide a quantitative and qualitative personalized impression of a location that was so elusive (and not imaginable) at the time of the AutoCarto Six paper. The accessibility to end users via the Web and smart phone-based devices, is now global. The intended and enhanced solution could now also be open sourced.

Today, low cost notebooks and laptops with huge data capacity and powerful RAM, as well as the current ability to gather consumer data and consumer preferences online and test new product ideas through the Web, has changed everything. The product/market matching system described in the AutoCarto Six paper would not only be economically viable for planning purposes, but it could easily be deployed as a consumer tourism information service. Ironically, what has changed the most is the diminished interest of the national government's perspective, appetite, and motivation for basing national tourism planning and development on this kind of an analytical approach. Although Bernie Campbell and Giulio Maffini have not been in contact throughout this 30 year period, we separately had excellent opportunities to apply the strategy and confirm its validity in tourism development planning.

We hope that the emergence of this retrospective may encourage national and provincial/state government agencies to consider or reconsider a stronger role in destination planning, marketing and development using the PMM concepts outlined in the AutoCarto Six paper of 1983.

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7

The Long-Term Functioning of Geographic Information Systems

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ABSTRACT. Data quality has taken a core position in the research agenda in the domain of geographic information systems over the past thirty years. The paper presented at AUTO-CARTO 6 played a role in this movement, articulating the role of ‘fitness for use’. However, certain issues remain, particularly those related to ‘long-term functioning’ rather than just data discovery. This paper revisits some of these issues.

KEYWORDS. Data quality, GIS, fitness for use, information management through time.

A. Title of AutoCarto Six paper.

The role of data quality in the long-term functioning of a geographic information system.

B. Reason for paper.

I attended the first two AutoCarto meetings in Reston in the 1970s. They provided my first public appearances, with some notable opportunities to establish the topological approach in opposition to the automated drawing packages of the era (the term cartographic spaghetti arose from that encounter). I missed the next two events. On my return to North America with the PhD, I rejoined the series with #5 at Crystal City. This was another Washington, DC event with substantial military mapping presence in close proximity to the Pentagon. Despite the emphasis on more traditional mapping, I identified my work with the GIS movement, and AutoCarto was the only real series that provided a forum to express ideas. I wanted my graduate students to attend.

So, I wrote a paper for the Canadian event, got accepted, and arranged to drive a University van to Ottawa (a day and a half from Madison through Sault Ste Marie and thence through Sudbury and down the Ottawa River). It was the scenic route, but worth the distance for the view of the country. The cost of my airfare would cover the van and lodging. The van held four of my students and an employee of Wisconsin DNR, Mark. We had a great time with cassette tapes of Grateful Dead marking the time.

At the border crossing late at night, Canadian Customs asked if we were all Americans. No, I said, one Indonesian with a temporary visa for Canada; eyebrows raised, no easy wave across the border. We had to go inside to get the paperwork stamped before we could continue.

On arrival in Ottawa, the AC 6 team had arranged home stays for all the students – a very generous offer not equalled in the current day. Mark and I did not qualify, so we stayed at the Youth Hostel – in the Nicholas Street Jail in downtown Ottawa. If we were quick in the morning, our work detail would be to raise the Canadian flag; otherwise we had to sweep the place.

So, the reason for the paper was to make a mark on the emerging community, to make a statement, and to bring my team along as a part of their training.

C. Thoughts shaping the design of the 1983 paper.

I finished my PhD research in 1982 (Chrisman 1982a) on the topic of a model of error in the polygon coverages that formed the core of early GIS developments. That work reflected my collaborations with colleagues at the Harvard Lab for Computer Graphics (particularly Geoff Dutton, Denis White, James Dougenik and Scott Morehouse, all under the direction of Allan Schmidt and Brian Berry). The PhD research at Bristol was under the supervision of Michael Blakemore and the counsel of Peter Haggett.

By the end of the doctoral research, my position at the Harvard Lab was nearing its end (for more detail Chrisman 1988, 2006). I took a position at University of Wisconsin-Madison, and embarked on a more traditional academic career. I returned to the AutoCarto series at number 5 in Virginia with a paper derived from my PhD (Chrisman 1982b). At that event, I was drafted into a new undertaking, the National Committee for Digital Cartographic Data Standards. At that point, we knew it would take some time, but twelve years was not what we expected.

I joined the Working Group on Data Quality with a collection of professionals across the mapping sciences, all of them much more senior (double my age). The intended chair of the working group did not materialize, and perhaps I showed myself a bit too eager. Before long, I was the chair of the working group, and certainly in charge of writing the reports. The work remained a collective process. I recognized that the process of drafting a standard would require careful choice of wording, and wiping out traces of personal viewpoints (a task some thought that I was not particularly suited for). It had to be a consensus document to stand any chance of adoption.

I started work on a white paper (initially for internal consumption of the Working Group) on alternatives (Chrisman 1983a, 1984). I relied on a great deal of discussion and input from the members of the group: Wallace Crisco, John Davis, Guenther Gruelich, George Johnson, James Merchant, Charles Poeppelmeier, George Rosenfield, John Stout, Frank Beck, David Meixler and others in the larger NCDCDS group. This process forced me to consider the role of data quality in a broader setting, and to consider the specialist knowledge of fields including surveying, geodesy, marine charting and photogrammetry.

E. Original contributions.

The AutoCarto 6 paper was not written as a standards committee document, so it could take a more personal and contentious approach. It started by firing a shot at both the view of map as graphic artefact, and at the topological model (that I had espoused so publically in prior AutoCarto meetings).

I asserted that the topological approach was necessary but not sufficient. What was lacking was the mechanism to maintain a database over time. I then laid out the basic argument for a data quality from the viewpoint of recording the sources and limitations in data collection.

In describing data quality, the phrase ‘fitness for use’ was used, and may be the reason for continued citation of the paper. The Working Group had already deliberated enough to make it clear that we would not fix arbitrary thresholds for quality, but leave the evaluation to the user. This was a departure from prior practice and long-established standards. There was much more in this paper, and perhaps it is not all read too closely any more. Certain issues opened up in this paper have become higher priority in recent years.

F. Impacts.

The oral presentation of this paper was late in the evening, for some obscure reason, in a session that had only my paper preceded by one presented by my PhD supervisor, Michael Blakemore, about accuracy of point data close to boundaries. The paper presentation started in a relaxed mood, perhaps due to the prior reception and alcoholic consumption of some audience members. Blakemore set the scene by drawing a huge string of bandanas from his back pocket, making allusion to my persistent habit of carrying a single (but color-coordinated) bandana handkerchief. He asserted that he had bigger bandanas than his student. This set a relaxed tone. The audience included many prominent personages of the era, all in a relatively boisterous mood.

My presentation included a moment when I asserted that data quality information would grow in importance, eventually surpassing the volume of data then occupied by the coordinates of cartographic features. This point was ad-lib, not in the prepared text of the paper, and was treated with some derision by prominent members of the audience, who may now disremember.

At that time, some commercial solutions provided one whole byte to record the ‘quality’ of a whole map sheet. What could one byte say? Good? Bad? Mostly harmless?

Fortunately that era is gone. I need only point to the volume of quality data stored in Open Street Map (Hacklay 2010) to record the lineage and accuracy of each point in that archive. Whole photographic images occupy megabytes to validate one XY coordinate and one address. Mooney and Corcoran (2012) report on accessing the complete historical archive of the past versions of OSM, something unobtainable from more traditional sources.

G. What was new in the paper?

The work of the NCDCDS working group established a more comprehensive framework for data quality, beyond the positional accuracy issue that had seemingly always been the primary if not sole issue in prior standards work. The adoption of 'fitness for use' moved the community away from fixed accuracy thresholds.

These were moves that were made through consensus and over a period of time. Each move was incremental, but this paper was a part of the process.

In addition, this particular paper started to deal with data sources as composites developed over time, and not simply snap-shots obtained on a specific date and treated in parallel through identical procedures. It argued for a 'full GIS' that would manage the 'long-term functioning' with procedures like distortion fields (now commonly applied for datum shifts) and reliability diagrams. Variations in data quality could be recorded and updated as changes were made.

H. What was different in the paper?

Due to dialogue with a broader range of disciplines, this paper opened up the issue of geodetic control as the base for GIS development. Most prior work simply started out on a projection plane and calculated away. This paper focused attention on the 'long-term functioning' of database maintenance long before the community had much experience with this kind of function. The concept of rubber sheeting was popular at the time and became particularly applied in the conflation procedures associated with TIGER (Saalfield 1985; White and Griffin 1985). The conversion from NAD27 to NAD84 operated with similar surfaces. Later work would provide for more nuanced object-based recalculation of positions (Karnes 1995).

I. Conclusions.

The primary result of this paper was greater visibility for the issues of data quality. The concept of fitness for use overthrew the prior attitude about fixed thresholds. The NCDCDS standards influenced the metadata standards adopted around the world, though certain items have been watered down over the years. The attachment to reliability diagrams and making the data quality a part of the spatial data has not been completely understood or adopted. I did manage to insert it in the Digital Chart of the World project (Danko 1992), from whence it made its way into the military spectrum of standards (VMap etc.).

The paper in 1983 was a step on the way to a longer term interest in temporal GIS, and some of the points made here then reappeared in better developed form in the work of Langran (Langran and Chrisman 1988). Further, certain arguments put forward here did not convince my colleagues in the working group, and thus did not make it into the standard. They remain challenges that must still be confronted, even if thirty years later.

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8

From Generalisation and Error to Information Overload and 'Big Data'

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ABSTRACT. The original 1983 paper looked at the effect of data generalisation when features coded as points (but were actually areas – business establishments) were being allocated to administrative areas. The main reason for this was the reliance on official statistical and geographic data that were constructed mainly as administrative units. Issues of error (the extent to which we could be confident an allocation was accurate) and liability (what were the consequences of using wrong data in policy analysis) led also to attention to the broader ethics of data use (for example privacy of individuals). Over the following 30 years the most significant shift has been towards non-governmental construction of geographic data resources (private sector, collaborative and crowed-sourced for example) as well as an increasing liberalisation of official data through freedom of information policies. However, the issues of accuracy, liability and ethics still resonate as strongly now as they did in 1983.

KEYWORDS. Geographic information, privacy, error, accuracy, ethics, liability, information society, integration, big data.

A. Title of AutoCarto Six paper.

Generalisation and error in spatial databases.

B. Context of the paper.

The 1983 paper was written in the context of 'lack of ...' There was a lack of sufficient spatial data, and geographical analysis was dependent largely on the provision of official government data whether it was from official statistics or mapping agencies. There was a lack of computing power to process even the relatively meagre amounts of data available, so we often had to rely on modest data sets and modest computing resources. There was lack of data at the right spatial aggregation, and the 'geographies' that we used for geographical analysis were more related to politics and administration than they were to the social, economic or environmental processes that were being 'analysed'.

Consequently error abounded, whether it was temporal (we were mostly reliant on data relating to the past when analysing the present, or forecasting the future), data aggregated to one particular geographical scale (the ecological fallacy), or to a geographical unit not related to our analytical needs (the modifiable area unit problem).

There were a few pioneers in processing of large data sets, arguing that microdata and spatial simulation were the optimal way of reducing error, such as Stan Openshaw's analysis of the siting of nuclear reactors (Openshaw 1982), but the widespread use of the 'wrong' data at the wrong geography was to lead to the schism in human geography between the hard spatial data analysts and the more discursive and qualitative human geography researchers (Openshaw 1991).

The conceptual basis for the 1983 paper had been provided first by Nick Chrisman in his 1982 doctoral thesis at the University of Bristol (Chrisman 1982). Now, there is a bit of lineage to be communicated here, because while I was officially Nick's supervisor I think that I learnt more from him, which is of course the ideal supervisory relationship.

The research relationship started when I was working with Peter Lloyd at the University of Manchester Graphics Unit, developing computer mapping packages. We were presenting our work at the Harvard Mapping Conference in 1979 (Blakemore and Lloyd 1979), and I vividly remember Nick telling me that he was going to research a PhD, it would be at Bristol (where I was working) and I would be his supervisor. While at Bristol Nick was on a sort of leave from the Harvard Graphics Lab (I'll leave Nick to tell you the details) to focus on the development of the overlay processor that was eventually to be the basis for the Harvard Odyssey GIS (and from there the journey to Arc/Info and the global impact of ESRI is another story (Rhind 1989)).

What Nick showed me in depth is that the lines on a map are not accurate demarcations of data, but are error-prone transition zones. This was to have a further impact when categorical data were overlaid in a GIS using relational databases. Take two coverages of data (one has 'aa' number of units and the second 'bb' units) and organise them in a relational database for overlay.

This was to be the research focus for Krysia Rybaczuk whose doctoral thesis (Rybaczuk 1991) shows that there are (aa * bb) number of ways of organising the data relationally, and that when each sequence is put through the same overlay processor the eventual overlay outcomes can be dramatically different. On a map coverage digitised from 1:25,000 maps some features were 'moving' up to 1 kilometre depending on the order of the vectors in the two coverages, even though the same algorithm was used.

A further key influence had been the work of David Douglas and Tom Poiker (Douglas and Peucker 1973), who showed clearly that when we digitise lines from a map they are themselves error-prone generalisations of 'reality'. Lines on a map in any case seldom exist on the ground. Administrative boundaries are not hard-painted on the ground, unless for example you are at the North/South Korean border, or during the days of the Berlin Wall, and I had the pleasure of exploring this in the historical context looking at the history of cartography with Brian Harley (Blakemore and Harley 1980).

Where did this all feature in the 1983 paper?

Well, Peter Lloyd's research project at that time was to analyse the industry landscape of north-west England. The data provided were for establishments which were geocoded (x and y coordinates) but which were to be grouped for analysis at a kilometre grid level. Pure point-in-polygon was easy, but the coordinate points related to establishments that had 'area'. So we simply (in white-hot FORTRAN IV code) put error bands at various levels around each point, and then assessed how many were uniquely in a kilometre grid square. We termed the band 'epsilon error', because that was a term Waldo Tobler had used in one of his earlier papers on error.

The not surprising outcome was that only a proportion of the points with error bands were uniquely in the polygons. With the current availability of Google Earth we could now simply look at the satellite images and make a decision about those where there was doubt, but in those days it required time-consuming fieldwork.

Sensitivity to error, and the use of technological tools, became among the core underpinnings of my research and business activities when I moved to the University of Durham. I was asked to develop further a labour market database that Durham operated on behalf of the Government.

The online NOMIS[1] service became the official release point of the monthly unemployment statistics, a source of the Census of Population, and a wide range of other data. In the early years of the service our focus was on how to manage what was a huge data resource and make it accessible online – and those were the days when 'connectivity' meant a telephone connection at the speed of a snail (300 baud), so communication efficiency was paramount. For that reason our early focus was on maximising data compaction (Nelson and Blakemore 1986) so that very large, but sparse, data sets could be accessed quickly.

Soon, however, we were sensitised to the effects of ecological fallacy (data were all aggregated to official administrative geographies) and the errors that may occur when area features (such as employment establishments) were coded to geographical units.

In what was known as the 'Census of Employment' each cohort of data was processed to give a postcode to the establishments, and then the postcodes were matched to geographical base units. The official statisticians responsible for the matching did not have ready access to the microdata from previous years and therefore did not know if an establishment had 'moved' across an administrative border due to a coding and matching error. NOMIS had the microdata and the software (Blakemore 1991) to 'clean' the data, frequently avoiding situations where a large factory had somehow leapt across a river into a new local authority – a process that added a new dimension to factory relocation.

If there was a prevailing theme emerging from the 1983 paper, it was that dealing with official geographic information was loaded with issues of temporal and spatial inaccuracies, which would have potential liability impacts for those who used the

[1] Still fully operational as www.nomisweb.co.uk and freely available to anyone.

information (Blakemore and Rybaczuk 1993). What it did not effectively foresee, however, was the explosion of private-sector data collection, or the growth of the online society and location-based services. Others did, notably those who built hugely successful GIS companies, location-based and navigation services, and geographic data developers and disseminators (Google Maps for example).

The focus that we often took on error and liability (Blakemore and Rybaczuk 1993) was very much conditioned by our experience with official statistics. For an official statistician a single error can be a reputational disaster, and who would be liable if someone used official statistics in a product where a user was injured? For the commercial sector, however, an error is a public relations challenge, and the rapid growth in private sector geographic information was to lead to a major shift in information priorities.

C. The ‘future’ development of the issues.

The shift towards the private sector dominance in much geographic information production was to challenge the capabilities and competencies of governmental sources in the ‘governance’ of geographic information. For example, the use of satellite imagery provided the private sector with the ability to generate data resources that were largely unaffected by political border control. So, if you want data for North Korea do you approach the official mapping agency of the ‘Hermit Kingdom’ or do you just go to Google Maps where satellite and crowd-sourced approaches are being used (Sang-Hun 2013), and the data are free?

Another example of the innovative approaches of the private sector occurred with the European Union (EU) Eurostat official regional statistics called REGIO[2]. European Union official statistics are built around the process of integrating and ‘harmonising’ statistics from the (currently 28) Member States. The governance is therefore vertically organised, with each Member State’s official statistics agency providing data. The process tended to run at the speed of the slowest supplier of statistics to Eurostat, which was frustrating for users of REGIO since it was the key source of official regional statistics for the EU.

The commercial producer Experian saw a commercial opportunity to build a competing version, and being free of the vertical politics it could simply generate its own direct (sometimes commercial) horizontal relationship with each national data producer. Since Experian was sensitive to market needs it ensured that as soon as each national producer released data it had access to the product. As a result it was able to produce a commercially competing product more rapidly, and at a fraction of the administrative costs incurred through the ‘official’ REGIO processes (EXPERIAN 2008).

Further manifestations of vertical governance were the huge efforts in building official spatial data infrastructures, involving the knitting-together of national spatial data coverages into infrastructures (SDIs) at the global level (GSDI 2003; Longhorn 1998), or

[2] http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics

at the regional level such as the EU with considerations also of the 'metadata' that would accompany the data (M. Craglia *et al*. 2002; Max Craglia and Blakemore 2004).

This tends to paint a picture of inertia versus innovation, and it would be naïve to label all official data producers as being organisationally sclerotic and bureaucratic. It also would be naïve to label commercial data providers as being always better. The UK Ordnance Survey, for example, is highly focused on update, detail, and customisation (SURVEY 2011b; SURVEY 2012), while also still contributing to the building of official SDIs such as at the European level (SURVEY 2011a).

But in many places the gap is still stark, as we found out in Egypt where the Egyptian Survey Authority was using state-of-the-art GIS to automate map data that were seriously outdated. As a result the potential clients of official data, such as telecoms, retail, and tourism, had largely generated their own independent and more updated mapping coverages of Egypt (Blakemore and Aikas 2006).

Furthermore, the situation now is not one of a simple public versus private data supply. Both sources can be used, for example the official national mapping of the British Ordnance Survey within commercial satellite navigation systems. This renewed the consideration of error and liability, where in March 2013:

> "*Norman Baker, Local Transport Minister, is today hosting the Government's first 'Satnav Summit' to thrash out solutions to end the misery caused when lorry and car drivers follow out of date directions from their satnavs*." (DFT 2012)

On a wider scale the attempt by Apple to enter the global geographic information market led to concerns that "*inaccuracies in Apple Maps could be "life-threatening" to motorists in Australia's searing heat, police have warned*." (BBC 2012), or where the maps routed vehicles across an airport runway (Kelion 2013). And, Google Map had the experience of the prevailing 'liability society' and risk-obsession where:

> "*Lauren Rosenberg is seeking $100,000 in damages after the accident in January when she tried to cross a busy state highway with no pavements at night and was hit by a car. A lawsuit filed in a Utah District Court last week accused Google of being "careless, reckless, and negligent" in supplying unsafe walking directions. Rosenberg's lawyer Allen Young said: "We think there's enough fault to go around, but Google had some responsibility to direct people correctly or warn them. They created a trap with walking instructions that people rely on. She relied on it and thought she should cross the street."* " (Kiss 2010).

The rapid growth of commercial 'big data', combining geographic base information with detailed statistics of personal behaviours, is resonating with many of the considerations noted back in 1983, but also is changing the power relationships.

The politics of information mean that governments cannot now simply censor their information to suit political ends, but also must seek to encourage or force commercial providers to censor their products, as in the case of the sensitivity over the ownership of islands between Japan and China (FOXNEWS 2013). The government in Norway also obliged Apple to modify its data coverage of Oslo (Kleinman 2013). Maps are not passive products but are now actively co-created with the users (crowd-sourcing) to enrich data coverage and to maximise timeliness (Goel 2013).

Sensitivities over privacy are amplified as the volume of personal data (from mobile phones, social networks, consumer purchases, health monitoring technologies etc.) provides increasing ability to track our lives, and the different national policies regarding data protection impose very different constraints on data producers, such as in Germany, for example, where this is a particularly sensitive matter (BBC 2013).

New relationships are being forged between citizens and government, where citizens are becoming part of the data analysis activity for city authorities, which transparently make available the same data as is accessible by city authorities (Feuer 2013). Geographic information is being directly embedded into products that were hitherto passive, as is the case with a walking stick (previously a passive piece of wood or metal) that is made ‘intelligent’ through the embedding of a GPS facility (Geere 2013). Real-time locational data can now provide more effective warnings of extreme events, such as tsunami warnings issued to those at risk in coastal communities (Morelle 2013).

If there is one strong parallel to the 1983 situation, it is that uncertainty, error and risk are still major considerations, but that the scale and speed at which they are impacting on the information community are greater than before.

As geographic information becomes embedded more pervasively in our lives, such as in automated cars (Bryant 2013; Will Knight 2013b), the impact of user behaviour will generate new risks, for example in the context of voice-activated cars (Richtel and Vlasic 2013) and accident risks, or the wider ethics of placing our ‘trust’ in robot systems, requiring ethical consideration of who is ‘liable’ for an accident, the human who is in the car, or the system that is driving (ECONOMIST 2012; Lin 2013). The behaviours of automated share trading systems have generated some learning lessons, where an error in one system can lead to a cascade of errors in other automated systems that track the behaviours of each other (Laurence Knight 2013a; Noble 2013).

As we move towards increasing global urbanisation, and more technologically-based ‘smart cities’ (ECONOMIST 2013; Wakefield 2013) increasingly detailed, accurate and timely geographic information will be both central to the systems and services, and also exposed to the issues of error, liability, and ethics.

D. Conclusions.

There are many other changes that could be noted since 1983. Access to information in 1983 was pre-Internet. While there was email, most of my personal access to literature involved a walk to the University Library and the amount of literature I could take from the Library was largely conditioned by how much I could physically carry.

Now, resources are increasingly online, electronic bibliographies mean I store more on my laptop library (indexed in a bibliography, documents attached and searchable, and it produces automatic bibliographies) than I ever could in my University office. It's such an exciting time to work, but then again, 1983 also was exhilarating.

Each generation innovates and moves the frontiers, and we all make predictions and forecasts that are variously inaccurate (Silver 2012), but the important thing is to review, conceptualise the key outcomes of the experience, and apply the learning lessons. Given forecasts of longevity there is some likelihood that I may even be around in 2043 for a 60-year retrospective. If I'm not, I just hope that people will be kind to me!

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A caveat: In the 'old' days there were these things called libraries, and if you could not find a book that had been cited in your own university library the kind librarians could request it from another library. After a suitably serene wait the book would arrive. Then resources appeared on the Internet, but because Website owners like to 'improve' them, they delete content, move it to other addresses, or the Website can simply expire. So, all the Web resources I cite have the date when I accessed them – honestly, they were really there on that date. If you cannot access it try putting the title into a search engine and see if it can locate another copy. If you fail to find it and are very keen to know what was written, then email me and I will try to help you – providing that I am still using the email at the head of this paper.

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9

What Ever Happened to the Statistical Surface?

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ABSTRACT. A longstanding theoretical construct in thematic cartography, the statistical surface, is defined as a cartographic representation of a continuous data distribution using methods customarily applied to mapping terrain. As of 1983, the concept had proven especially useful for exploring volumetric information (e.g., population density, disease rates, land value) using the analogy of analyzing a physical landscape. This retrospective paper looks at how the concept of a statistical surface has been expanded upon over the past three decades of GIScience research. Advances in processing technology and conceptualizations of space and time have modified the concept substantially, although it is unclear if current developments were a direct and conscious extension of the original concept.

KEYWORDS. Statistical surface, GIS, GIScience, spatial cognition, topology, map design, remembered geography, cartographic data modeling, Q-Analysis, 3D modeling.

A. Title of AutoCarto Six paper.

Topology and the concept of the statistical solid.

B. Reason for paper.

The intention of my AutoCarto Six paper was to highlight the potential advantages of automated construction of true 3D displays of statistical distributions which could be accessed in statistical space or in geographic space. Statistical surfaces were widely adopted at the time of AutoCarto Six, mapping many types of volumetric data using strategies developed for terrain including contours and fishnet surfaces, and prism maps to represent continuous thematic data (Robinson 1961; Jenks 1963).

However, these surfaces were limited to a birds-eye view, without considering the analytic benefits of shifting to a true 3D display. I hoped to demonstrate the advantages of “moving around” in the statistical space, not limiting oneself to looking at a manifold draped over a data volume, but wrapping the volume completely and treating it as a polyhedron, with abilities to explore the internal structure.

Beyond looking at surface morphometry. I also hoped to demonstrate the benefits of examining the data not only in geographic space, but in statistical space. At the time, I was limited to a very simple example, and to constructing my statistical solids by hand.

In 1983, quantitative geographical analysis had advanced to a point where multivariate methods such as cluster analysis and regression modeling were frequently reported in the geographic literature. However, the computer graphics technology supporting three- and higher-dimensional displays was still crude and cumbersome, due in large part to slow processor speeds.

Graphics display capabilities such as 3D pan, zoom, and rotate were not available in most commercial mapping packages, and the earliest 3D animations displayed only wireframe models (Catmull and Parke 1972). Interactive fly-throughs, Virtual Reality Modeling Language **(**VRML), and immersive viewing would not become widely available for a decade.

Data brushing to link geographic with statistical displays was included on many geographers' "wish lists" but was not to this author's knowledge implemented for another six years (Monmonier 1989). Commercially available GIS databases could accommodate true 3D coordinates, and multi-dimensional analytic functions were readily available through statistical packages. Yet links between the two types of packages did not exist in 1983, and neither type of software environment provided interactive display capabilities at the time.

C. Thoughts shaping the design of the 1983 paper.

The paper was motivated from several directions. My undergraduate education at Clark began in Psychology and shifted over to Geography, finally focusing in thematic cartography. I took courses taught by David Stea and Jim Blaut, and then completed several years of cartography courses taught by George McCleary.

Their ideas on cognitive mapping, remembered geography, and map design definitely guided my early interest in cognition, a sense of place and visualization. Several readings were particularly important (Lynch 1960; Downs and Stea 1972; Wood 1973; Gould and White 1973).

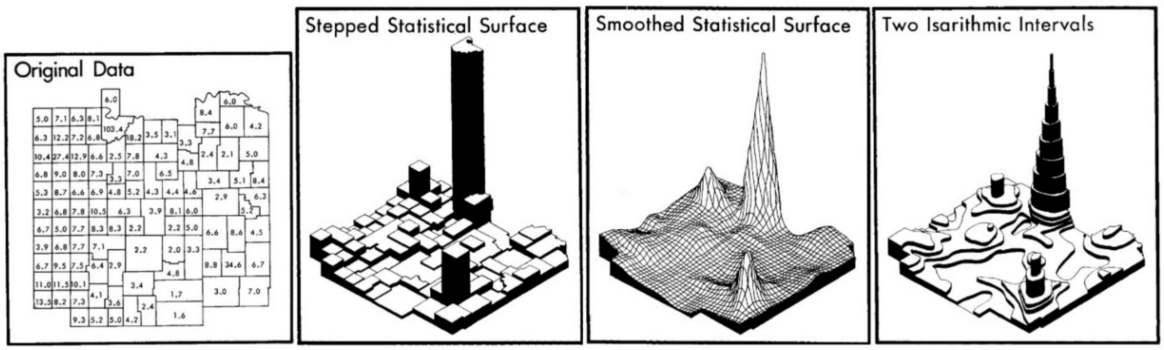
The second, equally significant influence emerged upon moving to Lawrence, Kansas to complete Master's work with George Jenks, who insisted that I ground my cartographic interest in design with coursework in statistics, calculus, and programming.

Grumbling about it at first, I soon realized that the skills George demanded that I master (before he would supervise my thesis research) would enable me to construct visual displays for analytical purposes, to consider spatial relationships in abstract statistical spaces, and to quantify and formalize other conceptual abstractions more effectively.

Jenks' initial article (1963) on mapping the statistical surface also provided important insights about the exploratory value of cartographic data modeling, that is, representing data by a variety of methods to deal with questions such as " How meaningful are spatial patterns evident in any display?".

His premise was that patterns which appear repeatedly in spite of different classing schemes, different numbers of classes, or different modes of display (stepped versus smooth surface depiction, for example) are probably valid, and bear further statistical analysis. Figure 1 shows four views of a population density data set (Jenks 1963); in every case, the display shows a 2D view of the volumetric data.

Figure 1. Four different views of a statistical surface of population density by minor civil division in central Kansas, 1960. The highest peak is located in Topeka (Jenks 1963).



D. Derivative attributions.

Two years prior to AutoCarto Six, I was working on my dissertation at the University of Washington, guided by John Sherman, Dick Morrill, David Hodge and (from Simon Fraser University) Tom Poiker. My dissertation research harbored no connection with statistical surfaces or thematic data, but my interest persevered in visualizing geographic abstractions.

Peter Gould published an intriguing essay (Gould 1981) that caught the attention not only of my graduate student cohort in Geography, but also of graduate students in Communications, Sociology, and Political Science with whom I worked in a campus computing facility (the Center for Social Science Computation and Research).

We shared hours of energized debate about Gould's acknowledgement that investigations in social science are often constrained by hypotheses and quantitative methods, and his advice that social scientists should investigate qualitative algebras which are less likely to distort patterns that may be latent in spatial data.

One such algebra is Q-Analysis (Atkin 1974, 1977), also called polyhedral dynamics, which formalizes descriptions of systems as having structure (a backdrop) and functions (traffic). Q-Analysis permits study of relationships among structural components and among functions for various systems.

In the case of my AutoCarto Six presentation, I prepared a Q-Analysis of residents' perceptions of selected places around Seattle, collecting information in a survey about what places they were familiar with and/or visited. I asked residents about distances between these places, and whether they could navigate to them, or direct someone else to them.

One additional derivative attribution occurred when I accepted an acting faculty position in 1982 at the University of California-Santa Barbara; Reg Golledge and I discussed cognition of urban areas and Q-analysis in some detail as I prepared the AutoCarto presentation. During this period I began to discover older literature on topology and psychology (Lewin 1936).

E. Original contributions.

One original contribution of the paper was a topological examination of the elements of a cognized urban image held consistently by residents who lived and worked at various places and job types in Seattle.

Topology is concerned with spatial properties such as connectivity, compactness, closure, and continuity. It involves the study of how those properties may be preserved when an object is transformed. I argued that a cognitive geography can be characterized by topologic properties that may be more strongly associated with familiarity, common activities, or a communally accepted identity, than with geographical proximity.

A second contribution was the proposal that the dimensionality of remembered places indicates the coherence with which they are embedded in a communal urban image. Nodes or isolated edges in the polyhedron are topologically weaker than fully bounded facets or solids, and by analogy, interpretable as being incompletely immersed and therefore less salient in the communal image.

Because the AutoCarto proceedings included only an abstract of my presentation, it may help readers to have a synopsis of my findings. Q-Analysis provided a means to construct a statistical solid representing residents' perceptions of landmarks, familiar places, and functional activities available in the early 1980s in Seattle (Figure 2). The topology of the polyhedron reflected the strength and integrity of various aspects of the urban activity space.

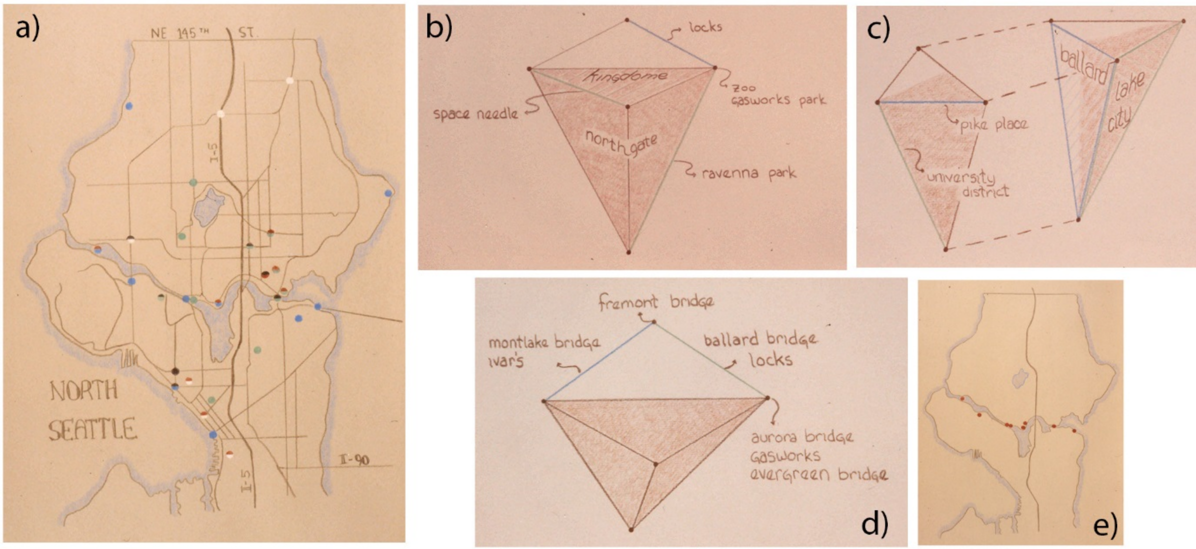
Five nodes anchoring the polyhedron shape included visual landmarks, recreational activity, water features, the university district, and Interstate 5.

The shaded area indicates the solid portion of the polyhedron, comprising recreational areas including the Northgate shopping center and the Kingdome sports arena. (Other areas are also contained in the solid but are not labelled).

Blue lines indicate activities along edges, for example the tourist attractions surrounding the Space Needle, the locks and salmon ladder in Ballard, the Ravenna Park mixed use neighborhood running between the University district and Green Lake district, and Pike Place Market.

A linear scaffold hangs off one side of the solid. From a geographic standpoint, the activity spaces labeled in Figure 2d appear to be connected because they are proximal to the ship canal (Figure 2e) running through the center of town.

Figure 2. Sites selected for the study (a); Two views of the backdrop of the Q-Analysis polyhedron (b and c); One linear arc of traffic (d) Along the ship canal (e).



From a cognitive standpoint, the scaffold carries a lower dimensionality than the shaded solid, and these places may be less prominent than the ship canal itself. Other linear traffic includes the tourist region surrounding the Space Needle and extending down to Pike Place Market. The polyhedron can be “cracked open” to reveal another facet community (Ballard) which appeared from the survey to be cognized more strongly for local residents than for tourists visiting the city.

F. Impacts.

I cannot claim with any certainty that my presentation made a direct or dramatic impact on the evolution of the concept of a statistical surface, except to me. This appeared in the *Proceedings* only as an abstract, not as a full paper, although I did present various aspects of the research at invited colloquia and conferences, and spoke with many colleagues informally about the work. I am not aware of other topologic examinations of remembered geography, although a group of computer scientists at Vienna University of Technology reported on ways that topological information can assist in spatial reasoning (Renz 2002).

I can nonetheless point to developments in the concept of a statistical solid that have appeared since AutoCarto Six, which demonstrate the maturation of the concept possibly independent of the arguments I made in 1983. It is more likely that these advances reflect evolved understanding of spatial statistics and spatial patterns, as well as reflecting technological advances that have occurred in ensuing years.

Technological advances in processing speeds and graphics hardware have made obvious improvements in 3D display and manipulation, as well as live data brushing environments, such as GeoVista Studio. Most GIS environments currently incorporate true 3D pan, zoom and identify. Statistical computing environments such as MatLab offer solid modeling capabilities, although many researchers prefer to write their own code. This appears to be a disciplinary choice, as for example for climatologists creating spherical models of global climate change.

I believe that pronounced advances in conceptualization of the statistical solid have emerged in spatiotemporal dynamics, and particularly for exploring individual and community space-time trajectories. Early conceptualizations were based in space time prisms and aquariums (Kwan 2000), and advanced data models which were polyhedron based (Worboys 1992). The statistical solid persists to the present time, although it is more often referred to in other terms: Song and Miller (2013) recently developed probabilistic models to describe spatial mobility in a space-time prism.

The statistical surface continues as a vital idea in its original conception, and is still presented in most cartography textbooks as well as in many GIScience texts. The terrain metaphor can be applied easily to representations of statistical distributions. Its analogy is intuitively obvious, easily depicted using current graphics technology, and remains useful for interpreting spatial pattern.

G. What was new in the paper?

I believe that my paper was the first to discuss the extension of a statistical surface to a solid form. It is also probable that the application of Q-Analysis to spatial cognition and assessing a sense of place among urban residents was original. In spite of constructing visualizations of my statistical solid by manual means (colored pencil on cardstock), I was nonetheless able to illustrate the multi-dimensional nature of a sense of place, and the importance of examining more than just the surface of a statistical distribution.

Another contribution was the linkage between statistical and geographic space, which facilitated the interpretation of spatial and semantic relationships in communal perceptions, as for example the importance of water in residents' image of Seattle.

H. Conclusions/Findings/Next Steps.

My 1983 AutoCarto Six paper extended the statistical surface concept from a manifold draped over a data volume to a statistical solid, a polyhedron whose surface could be explored by traversing the wrapper, or whose interior could be examined to understand internal structure and relationships, that is, the topology of a coherent urban image.

What did I benefit by writing this paper? I could test the idea empirically and gain feedback from colleagues who were conversant with the idea of a statistical surface, who had utilized it in their own work, and who gave me constructive and informed criticism to refine my own thinking.

I may not have taken the opportunity until now, as I write this paper, to reflect on these insights "whole-cloth"; but nonetheless as I look back, I find that my presentation back in 1983 was a prophetic reflection of one direction about to undertaken by a sector of the GIS community.

Whether that direction was taken independent of my paper is less important than acknowledging that the GIScience community continues to conceptualize and implement methods to represent abstract concepts about spatial and (more recently) temporal relationships, and to do so in ways that are ably supported by graphic and cartographic depiction.

Future research is likely to continue advancing understanding of these relationships, to the extent that we continue to explore the utility of metaphors as rich as the terrain concept that initially drove conceptualization of the statistical surface.

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10

Exploratory Steps towards the Contemporary World of Geographic Information and Unexpected Consequences

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ABSTRACT. The original AutoCarto 6 paper described some of the experiments carried out in the early 1980s as part of a part-formal, part-organic programme to arrive at a national topographic database. The paper addressed three primary questions – What was then possible by use of commercial digitising facilities?, How could the very large projected volumes derived from converting all existing quarter of a million Ordnance Survey of Great Britain (OS) maps to computer form be handled using parallel processing?, and What were the extra-OS determinants of topographic change as recorded in OS maps? Some of these issues have been long superseded by new technologies but others remain challenging. This new paper describes the context in which the work took place, the results of the research and subsequent (unanticipated) developments which led to the creation of the world's first complete and continuously maintained national topographic database[1].

KEYWORDS. Ordnance Survey, national topographic database, digitising, parallel processing, change detection.

A. Title of AutoCarto Six paper.

Towards a national digital topographic database: experiments in mass digitising, parallel processing, and the detection of change.

B. Reason for paper.

My focus was on sharing news of UK experiments and eliciting comment and ideas from international colleagues. The paper was centred on the best approach to converting some 230,000 basic scale maps[2] of Great Britain into a computer form such that many

[1] For reasons which will become obvious, part of this paper is written in the first person.

[2] In the world of paper mapping 'basic scale maps' are the largest scale Ordnance Survey maps available for any locality. Many derivative – usually smaller scale – spinoffs were made from them. Of the 216,044 basic scale maps included in the experiments, 54,365 were published at 1:1250 scale (each covering a 0.5km square), 158,020 were at 1:2500 scale (covering a 1km square) and 3,659 were at 1:10,000 scale (covering a 5km square). Subsequently the number of maps which formed the basis of the digital database rose to over 230,000.

uses were possible, including mapping. Beyond that, it was also founded on the need to find cost-effective ways of maintaining the currency of the resulting database.

Ordnance Survey had commenced digitising these maps in 1973 – the first national mapping organisation to implement a production line of this sort. By the time of the paper some 17,493 maps (8% of the total) had been digitised (virtually all in-house using manual line-following methods). These were available in digital unstructured form being originally designed for the creation and editing of paper maps. However previous experiments (Thompson 1978) had examined ways in which such ‘spaghetti’ (i.e., unstructured vector data) might be reformed into topologically structured and ‘clean’ data by automated means.

Despite this early work and the (obvious to some) long-term desirability of a truly coherent national topographic database, there was much uncertainty about how best to proceed. As reported later, the multi-sectoral team of authors, the research findings, networks of experts, and a serendipitous event some eight years later had substantial effects on the development of the first national topographic database in the world.

C. The context.

For those not actively engaged in the GIS world in 1983, it is hard to comprehend the gulf between then and the current situation.

Computer power on any scale was a research facility. Indeed, wider access to <u>any</u> computing power was very limited: the IBM PC had just been launched two years earlier. In the UK, use of aerial imagery as end products was rare; more globally the use of satellite remote sensed data was largely confined to university and government research labs mostly using home-grown software.

In general, digital geographic (and other) data was scarce, and access to what existed was often restricted due to policy, cost or computing factors.

Networking was primitive and restricted mainly to universities and research labs: the internet was in its infancy, Berners-Lee’s invention of the worldwide web was still six years ahead and the first successful web browser was a decade ahead.

Collaboration between academics and government was much more limited than now. Academia was both much smaller in scale and saw teaching and papers printed in professional journals as the sole metrics of merit. Commercial enterprises involved in GIS were small niche players, enormously different in size and influence compared to Google and other contemporary giants. The key institutional players were government bodies like the U.S. Geological Survey.

D. Derivative attributions.

The expertise of the paper’s authors was highly complementary. Rhind was then a university professor who had been involved in mapping and GIS for 16 years and who had – to the despair of some academic colleagues – acquired some skills in interfacing with government and learning ‘management speak’. Adams had completed his PhD a year earlier on raster data structures and topographic data using a pioneering parallel processor. Fraser was a surveyor of long-standing and wide experience in the military, and in Ordnance Survey where he was head of research. Elston was an expert in statistical sampling and analysis, based in what is now the UK’s National Centre for Social Research. Apart from their own expertise, each brought a formidable list of contacts, advice, and help to the project.

E. Original contributions and results.

The paper set out to explore three key questions:

What was then technically feasible from commercial organisations by way of digitising the remaining 92% of the OS basic scale maps?

All known manufacturers of automated digitising systems were circulated with details of the project which involved digitising a ‘representative’ 1:1250 scale OS map and coding the results. All bar one were raster-based systems. The main conclusions included the discovery that most of the raster-scanning purveyors could not at the time provide vector output quality comparable with, and none were as cost-efficient as, the existing OS manual systems. The former shortcoming was attributed to the software, rather than the scanning hardware, and the presence of broken (e.g., dashed) lines in the source documents.

How could novel computer architectures, especially parallel processing, cope with the likely volumes of data? The starting point for this was an early part of Adam’s PhD work (with the help of Ordnance Survey) which led to the Adams and Rhind (1981) paper projecting the final size and other characteristics of a national topographic database; These characteristics were so challenging as to necessitate much more powerful computing facilities than were then generally available.

This part of the study used both simulated raster data decomposed from pre-existing vector data and the output from the digitising study (above). The work employed the ICL Distributed Array Processor (DAP). It differed from the contemporary or earlier Goodyear Staran or Illiac IV parallel processors in having many more (4096) processing elements, though these were more limited in the range of applications which could be achieved. The DAP could perform phenomenally quickly for certain applications which suited its architecture. For building vector land parcel boundaries from raster data for example, it operated at around 1000 times faster than one of the then-largest commercial computers, the IBM 370/168.

To take full advantage of the DAP architecture necessitated hierarchical structuring of the data using quad trees. Given that these only appeared in the computer science and engineering literature in the period 1974 to 1980, this was a very early practical use for search, retrieval, and aggregation/generalisation of real (c.f. test) spatial data.

What were the drivers of change to topographic detail shown on Ordnance Survey maps? This sought not only to identify these change drivers, but sources of information on up-coming change (e.g., local government planning permissions) or recent change. This was important because OS had recently completed up-dating all its large scale national maps and hence the main future task was to keep them very up-to-date to meet the needs of land registration, the business systems of the utility organisations, and other key users.

Identifying causal factors is often difficult and is especially so where the causes are multiple, interacting, and operating over very different time scales.

For example, we knew in general terms that most of the topographic change in the densely populated UK was due to human factors and that this varied greatly between different areas. Moreover in any one area the rates of change had varied over time. The greatest rates of change in the 1980s tended to be at the edges of urban areas, by the infilling of large gardens with new houses, or in areas of comprehensive redevelopment. In earlier times the greatest rate of change occurred in rural areas (e.g. in the enclosure of farmland in England in the eighteenth century) and in urban areas (e.g. in urban slum clearance in the late nineteenth century). Change drivers could also be very local as well as national, especially given the level of detail recorded on detailed OS maps (such as extensions to houses).

This formidable task was tackled by selecting a sample of 3000 OS maps stratified by population per map sheet, the proportion of owner occupiers, and the map scale (since this influenced what was recorded). Two field surveys of all the sample map areas were carried out by OS surveyors one year apart and, from these, the magnitude of the changes in each map area and each stratum was computed.

Information on various possible drivers such as past change, planning consents, national and regional economic indicators, and land cover/land use were used. Correlations between change and the different factors were computed and regression analysis was used to model the relationships. In reality the within-class variance was very considerable but some indicative results were achieved.

F. Results and Impacts.

The results described above had both short- and long-term significance. The digitising results partially led to the heavy use by OS of the Laserscan automated line following digitiser, but also provided an introduction to the world of commercial digitising – which proved to be valuable later when OS out-sourced most of that work.

The Distributed Array Processor work proved to be of academic significance, but had limited practical consequence because of the commercial failure of the DAP. The study of determinants of change was used in reconsidering what sources of information OS could obtain to give it both specific and country-wide information on ‘average’ past and predicted forthcoming change, thereby enhancing the organisation’s capacity to plan the allocation of its then 1000 or so surveyors.

In the period from 1969 to 1991 I was at various times a collaborator with, consultant to, and critic of Ordnance Survey. The work described here was an important building block of my education, and part of OS' growing engagement with the academic sector (a demonstration of how seriously they took the work was the allocation of field surveyors' efforts to map change in 3000 map sheets scattered across the country in each of two consecutive years).

The greatest impact of the research described in the original 1983 paper and other work in the 22 year period cited above, however, was almost entirely serendipitous.

Following pubic advertisement of the job and competitive interviews, I was appointed Director General and Chief Executive of Ordnance Survey. I took up post in January 1992, soon after launching a manifesto for the reform of the organisation at its 200th anniversary conference (Rhind 1991).

The appointment was a surprise to many. I was the first Director General who did not come from a surveying background, who had never served in the military, and who had not previously managed a large organisation (a government department then with 2400 staff). Whatever the reasons for my appointment by Ministers on the advice of the Civil Service Commission, the next seven years gave me a huge opportunity and proved to be a revolutionary period in Ordnance Survey.

Rhind (1997) described how the leadership and staff of OS radically changed the organisation in this period. The main changes and tough decisions which were made included:

- The acceleration of digitising, leading to completion of all the OS maps in vector digital form in early1995, rather than 2005 as had been predicted in 1987.
- The continuation of digitising 'spaghetti' for most of the rest of the maps rather than starting again and adopting newly sophisticated digitising techniques which provided much cleaner and topologically structured data.

  That decision was partly based on the research previously described which had demonstrated in principle that software solutions could be 'productionised' to create structured data. This proved to be correct and subsequently led to the OS MasterMap, the core of OS' present products and services.
- The launch of a printing on demand mapping service in late 1992 in shops across the country, producing large scale maps with the customer selecting the area and the map content.
- A major restructuring of Ordnance Survey which, facilitated by the database creation and adoption of new technology, included a reduction in pre-existing staff from 2400 to 1550. The slimmed organisation was then augmented with 300 additional staff with IT expertise, many from outside the public sector.
- The rapid introduction of digitally-based collaborations with the private sector, including joint ventures (such as scan digitising half a million OS historical maps dating from the mid-nineteenth century to the 1960s); this also included a shift from use of software created largely in-house to commercial-off-the-shelf (COTS) products.

- A greater focus on customers, including customer satisfaction surveys, complaints analysis and marketing, plus a focus on accountability to Parliament and enhancing Members' understanding of OS' work.

  This all led to success in reducing the cost of Ordnance Survey to the UK taxpayer from £22m in 1992 to £2m in 1997, whilst also widening the range of products, maintaining quality, and raising OS' reputation amongst politicians and the public.

- The launch of a Geographic Information and Mapping Services (c.f. products) facility to generate new business.
- The launch of an annual OS research summer school.
- An increased presence of OS staff at leading international conferences and on committees beyond the traditional areas of surveying.

G. What was new in the paper?

The new elements of the paper were partly the use of then-novel technology and partly the attempt to quantify the drivers of topographic change. The latter may be considered an early example of Geographical Information Science (Goodchild 1992). Also novel in the context of the time was the close-coupling of team work by a group of academics (geographers and computer scientists), senior staff from a government department, and statistical researchers.

H. Conclusions.

It may seem fanciful to link one (albeit important at the time) research project with the fundamental changes wrought later to a national mapping organisation. Whilst many other elements were involved, this particular project can, however, be seen in retrospect as a seminal event and particularly timely.

Ordnance Survey has survived and prospered over the last 20 years as a consequence of the reforms described and by continuing to be innovative, being outward- and forward-looking, and anticipating the changing needs of users for topographic and related data. Not all NMOs have been so fortunate: it is fascinating to read of current efforts by other national mapping organisations to adapt to the new digital world and to the dynamism of private sector organisations (Coordinates 2013, UN-GIMM 2013).

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J. Acknowledgements.

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11

The Design of Maps for Telidon: Interactive Design of Maps Revisited

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ABSTRACT: This paper revisits the original presentation in the Design of Maps for Telidon which appeared in the Auto-Carto Six Proceedings. Although the technology has changed dramatically and maps on screens are now commonplace, this early example of the challenges of map design for screens and the ways in which content is selected and presented remain. Some limitations present in 1983, such as cost, have been reduced and public access to maps in digital form is now commonplace. This paper argues that the potential identified in 1983 by Telidon has now been realized and maps on screens are now ubiquitous, and are available to individuals on demand on an increasing variety of personal digital devices.

KEYWORDS: Telidon, videotex, public access, maps on screens, ubiquitous cartography.

A. Title of AutoCarto Six paper.

The design of maps for Telidon.

B. Introduction.

Telidon was a videotext system developed by the Department of Communications in Canada in the late 1970's. Telidon had what for the time were good graphics capabilities. Videotex systems were very popular at that time and allowed the display of information in a remote database directly on a television set using the telephone or cable as a communications device. The innovation developed by the Department of Communications through Telidon improved graphics quality and capability.

Vidotex systems at the time were using mainly an alphamosaic approach which produced very crude graphics. Telidon used an alphageometric approach using Picture Description Instructions where graphics were described by combinations of lines, circles, rectangles and polygons and both these and the drawing commands were very similar to the approaches used in many of the computer mapping programs of the time. This made Telidon useful for cartography and the paper described how software interfaces were written between existing computer programs of the time such as GIMMS and MIGS which were described elsewhere in the Auto-Carto Six Proceedings. The original paper identified the potential for Telidon and at the same time some of the limitations and challenges for its use. In 1983 I argued that “In technical terms there are several computer mapping systems which can produce maps more effectively than Telidon, but none which can give the same possibilities for wide distribution. The hardware required for Telidon consists of a TV set, a telephone or cable hook up, and a decoder which in June 1983 cost approximately $1200. The cost is likely to decline and several manufacturers (e.g. Apple) are already producing videotext boards for the home micro-computer….The potential exists, possible for the first time, of the widespread distribution of maps and other geographical information in digital form. This poses new communications and design challenges.” (Taylor 1983, p.463).

In revisiting the paper I was struck by just how innovative the development of Telidon was. The use for cartography was unique and set the stage for any of the future developers of maps on screens, including on personal digital devices which are commonplace in 2013. The potential for mass distribution of cartographic products identified in 1983 has now been realized. In technical terms many of the limitations of Telidon have long since been resolved by new technologies and approaches but the central challenges of effective communication and design still remain.

C. Communication and design for maps on screens.

It was argued in 1983 that communication by a TV screen is inherently different from that of a published map. This, it was argued, was caused both by the nature of the process of TV transmission at the time and the brains response to it. The TV transmission process was unlike any other medium. There was no actual picture being projected. Television worked by electronic scanning in which tiny dots of light were “fired” one at a time across alternate lines of the screen. An image was created every thirtieth of a second. At any one moment there was never more than one dot of light “glowing” on the screen. The entire image was seen because the brain fills in and completes 99.9 percent of the scanned pattern each fraction of a second. The only actual picture that exists is in the mind of the viewer. Creating maps on a TV screen using a videotext system such as Telidon therefore posed special problems and research was carried out to test user reactions to various approaches, especially on the effect of presenting information sequentially.

Although the production and dissemination of maps on TV screens did not develop much further due to rapid change in alternate technology, the production of maps on screens grown exponentially. Initially dissemination was through computer screen maps on personal computers but was rapidly replaced by distribution on a wide variety of personal digital devices. The challenges of design have actually become much greater as screens get smaller. In the 1983 paper a comment was made about the potential use of colour and sound to overcome some of the difficulties. Both of these elements are widely used today and experimentation with multi-sensory and multi-dimensions of cartography through approaches such as cybercartography (Taylor and Lauriault 2014) are now growing in importance.

D. User testing and interaction.

In 1983 we were still in the supply era of cartography where the user received what the designer or producer created. There was user testing carried out but this was primarily testing user response to different kinds of presentations. Research related to Telidon broke new ground in terms of testing users' responses to maps created on TV screens but research in this respect was in its infancy. We have come a long way since that time but challenges still remain in the effective design of user interfaces and interactive functionalities. Here, cartographers have much to learn from the field of Human-Computer Interaction, both in the design of better interfaces and in the important issues of both use and usability. As new cartographic technology develops the tendency is to concentrate on new "bells and whistles" as opposed to user response to those technological developments. Multimedia and multi-sensory approaches will certainly attract user attention but will they lead to longer term learning or will information overload accrue?

E. Availability of cartographic products.

The 1983 paper suggested that perhaps for the first time the potential of making maps widely available to the general public directly in their homes existed using the ubiquitous TV set. With the advent of Google Maps, Google Earth, Bing and others this is now certainly the case and maps are not only available in the home but on mobile personal devices. Maps by supply have been replaced by maps on demand on an individual basis and increasingly the division between map user and map creator is being blurred with terms such as "prosumer" appearing in the literature. Increasingly through "crowd sourcing", "volunteered geographic information" and social media and networks individuals and groups are creating their own maps. Location-based services and information are now central to everyday life and maps and mapping are even more important to how society functions.

E. Conclusion.

Technological change has been very dramatic since 1983 and has affected cartography in many ways. The 1983 paper on Telidon was an early example of what is now ubiquitous in cartography, the wide availability of maps on screens.

Some of the central design and communication challenges, however, still remain, albeit in a very different technological context.

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12

MIGS: From Cartographic Revolution to Evolution

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ABSTRACT: The purpose of this paper is to summarize the innovative features and capabilities included in a microcomputer cartographic system developed in the early 1980's in the Department of Geography & Environmental Studies at Carleton University, and how the technology has evolved. The basic underpinnings and design features can still be seen in contemporary systems used today. It was argued that its ease of use and inexpensive cost could make it a suitable system for developing nations.

KEYWORDS: Automated cartography, MIGS, ZAPPER, microcomputer-based mapping, line simplification algorithms, interactive digitizing and plotting.

A. Title of AutoCarto Six paper.

MIGS: A microcomputer mapping system for cartography in developing nations.

B. Introduction.

The original paper co-authored with Fraser Taylor described a simple and novel microcomputer-based vector mapping system for producing choropleth thematic maps of quantitative geographic data of areas of interest. As microcomputer technology was relatively new in those days, and fairly limited in the power and capability of the processors, having a standalone, portable thematic mapping system that was easy to use with a menu-driven, text-based user interface, was a huge improvement over large, mainframe-based, punch card and dumb terminal software systems. It was proposed that such a simple system could be used in developing countries with limited computing resources to potentially map various demographic and physical data sets.

C. Reason for paper.

The original paper was written to showcase the MIGS system (Microcomputer Interactive Geocartographics System) as it was named, reflecting the fact that it was microcomputer-based, the interface was keyboard interactive with the user, and it produced vector cartographic maps with associated cartographic elements like legends, scales, north arrows and text, all being output to an HP vector pen plotter. The system was relatively inexpensive and used standard computing hardware of the day. By presenting the system at the AutoCarto Six conference, it demonstrated what was capable in the field of cartography with very simple hardware and software, and the quality of cartographic output.

D. Impacts.

Being developed in an educational institution, the system was also successfully used in the Carleton undergraduate course ‘Analytical and Computer Cartography’ for many years, before other mapping systems were commercially available. Not only did the students use the system for producing maps, but were taught and demonstrated some of the algorithms and mathematics behind the software to de-mystify the ‘black box’ system. Various modules had to be used in a proper sequence, but that gave students insight into the complete digital cartographic process. It was truly a time where software development was rampant as the cartographic community embraced the new technologies that applied to their discipline.

The mapping system was a major improvement in a university educational environment, as it evolved from the mainframe, punched card systems of the day like Symap, Simvu and GIMMS to a local, floppy/hard disk microcomputer configuration used just a few years ago. The system proved that microcomputer technology could perform the various complex tasks required to create a digital hardcopy map, and it was in production even before systems like MapInfo came on the scene.

E. System design.

The paper basically described the design, modules, capabilities and output options that were available in the system. Hardware requirements were a North Star microcomputer, a Summagraphics digitizing tablet for locational data input, a 5¼” floppy disk for data storage and a Hewlett-Packard vector pen colour plotter for hardcopy output. In subsequent versions, the software was ported to newer microcomputer hardware platforms as computing equipment was rapidly evolving, and storage went from 5¼” 720Kb or 1.2Mb floppy disks to 8” floppy disks to 3.5” 1.4Mmb floppy disks to 20Mb hard disks. Hard drives were a major innovation at the time, and permitted larger data sets and faster processing times. Slowly, the power of the mainframe was being placed on the desktop.

F. Originality.

The system was developed from scratch and attempted to include all the features required to digitize topological line work, create polygons, edit, input data, categorize data, and output the results to a vector pen plotter for hardcopy output. As part of the educational use of the software, a subset module named the Zapper Line Simplification System was developed that demonstrated twenty or so line simplification and smoothing algorithms as they processed vector linework, in real time, with associated animated graphic displays of the process in VGA (Video Graphics Array) resolution of 640 x 480 pixels. ZAPPER was inspired by papers written by McMaster (1987, 1989). Of course, the ZAPPER module had an implementation of the famous Douglas-Poiker line simplification algorithm, one of the most popular and widely used line simplification algorithms of the era, and still in use today. Unlike the static images of the interim steps in the Douglas line simplification algorithm, the ZAPPER system permitted the user to take any map (data formatted appropriately) and view a real time animation as the algorithm proceeded to simplify the vertices on the vector linework. It was a true innovation at the time.

Also, a globogram projection and pillar map capability was developed, emulating the popular globogram maps produced in the Geography Division of Statistics Canada. Showing a global perspective view of a map, the globogram module incorporated line simplification in the most northern parts of the map, removing line density issues and thereby improving the look of the output.

G. What was new?

As computer graphics systems were rapidly being developed, a logical progression for the system and a pioneering option was the creation of the TELIMIGS system. Instead of producing hardcopy map output on a graphics plotter, the TELIMIGS software converted graphics primitives and maps to Videotext format and sent them to a Telidon terminal, a device developed by the CRC (Communications Research Centre) in Ottawa, Canada. This terminal box processed NAPLPS (North American Presentation Level Protocol Syntax) videotext, a hardware/software system capable of displaying text and graphics which, at the time, was a precursor to our current internet file server/information and graphics transfer and display systems of today.

The system was also capable of converting its internal file format into GIMMS format (a mainframe vector mapping system developed by the late Tom Waugh of the University of Edinburgh and initially used at Statistics Canada as their main map production system). In time, various other GIS and mapping format conversions of the era, similar to systems like Safe Software's FME data conversion software of today, were developed for data exchange.

Other capabilities included spaghetti-like digitizing and topological digitizing with automatic polygon creation, point reduction algorithms, globogram projection styles, various point, line and polygon editing tools, and a text module for placing text at polygon centroids and for creating titles. Automatic legend, scale and north arrow modules rounded out the features. Subsequent iterations of the software had on-screen graphic displays when that technology became available The system was written in the procedural based, high level programming language called BASIC, acronym for Beginner's All-purpose Symbolic Instruction Code, which later evolved into QuickBASIC and then VisualBASIC. Even with this simple programming language, which natively contained capabilities for sound, graphics, communications and disk operations, it was amazing what could be done with what you would call a primitive language today.

H. Conclusion.

The topological data structures, automatic polygon building, editing facilities and output features contained within the system are typical of modern vector mapping and GIS systems of today. The major difference is in the power of the hardware and features of the software – what would take hours to print a hardcopy vector map now takes only minutes.

However, with this power comes complexity, but also flexibility, so much so that the modern cartographer's toolbox has switched from pen, paper, scribe coat and such to digital files, sophisticated graphics software and hardware with GUI's (graphical user interfaces), dialogs, layouts, templates, previews and support for a variety of hardcopy output devices.

Previously, a single user interacted with the software on their desktop, but now it is easy to collaborate with users and colleagues and use multiple sources of information by embracing the most recent cloud computing innovations being introduced by software developers. Today, tablets and smartphones have entered the realm of cartography with GPS capability and world maps and directions at your fingertips! But has the computer replaced the trained cartographer as far as artistic design is concerned – well, that is still in the hand of the cartographer holding the mouse!!

This author is just glad that he was able to be a part of the cartographic revolution at the time, and looks forward to the innovations being developed for this exciting field in the next 30 years.

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Part III

SPECIAL SESSION RETROSPECTIVE PAPERS

13

L'évolution de la cartographie thématique sur micro-ordinateur

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RÉSUMÉ. En 1983, la micro-informatique était naissante, et les quelques logiciels de cartographie accessibles étaient réservés à des « gros » ordinateurs. La communication faite à AutoCarto Six faisait l'hypothèse qu'un environnement micro-informatique pouvait supporter des applications de cartographie thématique. Les dernières décennies ont évidemment confirmé cette hypothèse. Mais, d'une part, c'est plus la structure portable et ouverte du logiciel qui s'avérait une originalité plutôt que le fait de s'appuyer sur un matériel particulier, désormais obsolète, et d'autre part, le rôle de la cartographie thématique s'est amenuisé au profit d'autres fonctionnalités offertes par les logiciels traitant aujourd'hui l'information géographique.

MOTS-CLÉS. Cartographie numérique, micro-informatique, données géographiques.

A. Titre la communication à AutoCarto Six.

Un logiciel de cartographie assistée par micro-ordinateur.

B. Objectifs de la communication originale.

Née à la fin des années 70, la micro-informatique ne s'est véritablement banalisée qu'au milieu des années 80, avec la large diffusion des premiers PC dédiés au monde professionnel (PC IBM XT et AT apparaissant respectivement en 1983 et 1984). Jusque-là, les ordinateurs individuels (Apple II, Commodore PET et Tandy RadioSchack TRS80 principalement) faisaient plutôt figure de stations de jeux pour utilisateurs fortunés ou de bancs d'essais pour amateurs d'électronique et d'informatique. L'informatique « sérieuse » utilisait des ordinateurs centraux (*mainframes*) et des stations de travail basées sur des mini-ordinateurs. La crédibilité du développement d'une application professionnelle sur micro-ordinateur était mise en doute, et le développeur devait avoir fait ses preuves sur des ordinateurs puissants et en utilisant des langages de haut niveau pour avoir droit à l'écoute de ses collègues.

C'est la situation qui prévalait lorsque je décidai de transposer un certain nombre de programmes de cartographie automatique que j'avais rédigés en FORTRAN sur IBM 370, vers un micro-ordinateur Apple II. L'autonomie offerte par la configuration micro-informatique (micro-ordinateur, écran, table traçante, tablette graphique et imprimante) et le temps de réponse rapide – tant lors de la phase de mise au point que lors de l'affichage des résultats des traitements – étaient bien sûr de sérieux atouts. Grâce à eux, le développement envisagé devait pouvoir rencontrer les besoins des petites entreprises, mais aussi montrer de larges potentialités didactiques dans l'enseignement de la cartographie.

Le développement de logiciels de cartographie automatique, de traitement d'images et de systèmes d'information géographique a constitué une large part de mon activité professionnelle durant toutes les années 80 et une partie des années 90. C'est à ce domaine qu'ont été consacrés ma thèse de doctorat (Donnay 1985 ; 1986) et les premiers contrats de recherche qui m'ont été confiés. Bien sûr, la démarche a profité de l'évolution rapide du matériel, et des PC en particulier. Elle a aussi embrassé un champ de plus en plus large d'applications (projections cartographiques, traitement d'images de télédétection, etc. ; Donnay et Binard 1993).

Mais les éléments clés posés dès le début de la recherche sont restés : une structure modulable, portable et ouverte du logiciel. Ils apparaissent déjà dans la communication faite à AutoCarto Six en 1983, et se sont avérés fondés jusqu'à ce jour. Le succès des librairies logicielles spécialisées (GDAL/OGR, GeoTools, etc.) et des logiciels libres et ouverts (*Open Source*) dans le domaine de la cartographie et des SIG en sont la preuve.

C. Considérations qui ont dicté la structure de la communication de 1983.

Les deux points les plus importants qui organisent la communication faite à AutoCarto Six sont, d'une part, la structuration des données géographiques et, d'autre part, la structuration modulaire du logiciel proprement dit. Pour comprendre l'importance de ces éléments, il faut se remémorer les contraintes liées à l'environnement micro-informatique de l'époque.

Le micro-ordinateur hôte est un Apple II Europlus, disposant au total de 64 Ko de mémoire centrale (48 Ko sur la carte mère et 16 Ko sur une carte d'extension). Les périphériques sont constitués de deux lecteurs de disques souples 5''¼ Apple (capacité de 141 Ko par disque), d'un écran monochrome exploité en « haute résolution » (208 x 192 pixels), d'une table traçante Houston (Bausch & Lomb) HIPLOT DMP2 (format Letter / A4) connectée en série, d'une imprimante Epson RX80 à aiguilles (matrice 9 x 9) connectée en parallèle, et d'une tablette graphique Apple (11'' x 11'', résolution de 200 dpi), reliée au micro-ordinateur par une interface spécifique de la marque. La configuration s'est enrichie par la suite (double écran, disque dur de 5 Mo, modem acoustique, etc.), mais les éléments décrits plus haut sont ceux disponibles au moment de rédiger la communication d'AutoCarto Six.

Cette configuration introduit trois contraintes importantes.

1. La première contrainte évidente est la limitation de stockage, tant en mémoire centrale, que sur disque externe. C'est elle qui a le plus d'influence sur la recherche d'une structure optimale de données et sur la modularité du logiciel.
2. La seconde contrainte à lever est celle du système d'exploitation (Apple DOS 3.3 à l'origine). Pour garantir la portabilité de l'application, il a fallu choisir un langage

de programmation indépendant et susceptible d'être compilé dans divers environnements.

3. Enfin, une dernière contrainte majeure provient de l'interfaçage des différents périphériques graphiques, soit à cause des contrôleurs de type propriétaire des appareils de la marque Apple, soit par l'absence quasi-totale de microprogrammes pour la commande des autres périphériques. Cette considération est à la base du développement de librairies graphiques, indépendantes des périphériques, et de la réécriture de contrôleurs réduits à leur plus simple expression.

D. Position de l'application par rapport aux travaux contemporains.

L'effervescence suscitée par l'apparition de la micro-informatique s'est surtout traduite par une multiplication de publications non scientifiques destinées aux amateurs d'électronique et d'informatique, et publiant tant les codes (ou pseudocodes) d'algorithmes et d'interfaces, que les plans de solutions hardware (exemples parmi d'autres : Johnston 1979 ; Beetem 1980). Parmi les revues scientifiques, on notera cependant que *Computers & Geosciences* et l'*ITC Journal* ont assez rapidement montré un intérêt pour les développements d'applications micro-informatiques (un exemple contemporain : Devereux 1985). Il est évident que toute cette littérature, plutôt technique que scientifique, a influencé sur le moment telle ou telle solution implémentée dans le logiciel de cartographie présenté à AutoCarto Six.

Mais pour en revenir aux manières de lever les principales contraintes créées par l'environnement de travail, les sources sont plus claires.

D.1. Portabilité et structure modulaire.

Dans l'ordre des problèmes à résoudre, il fallait d'abord assurer la portabilité de l'application par l'usage d'un langage et d'un système d'exploitation adaptés. La solution retenue utilise un système d'exploitation écrit dans un langage évolué, et non dans le langage machine du processeur, en l'occurrence le P-System développé par l'UCSD (*University of California at San Diego*) et écrit en Pascal (Bowles 1979). Les différents langages évolués (FORTRAN, Pascal, ADA…) supportés par ce système sont compilés en code P, portable et indépendant du processeur. Le code P est ensuite traduit dans le langage machine d'un ordinateur hôte grâce à un interpréteur dédié. Grattery (1982) signale qu'à l'époque, 80% des ordinateurs acceptant le langage Pascal supportent un tel interpréteur du P-System. Le système P et son interpréteur pour le processeur 6502 sont implémentés sur Apple II, avec carte d'extension mémoire, sous l'appellation Apple Pascal (Apple 1979 ; Luehrmann et Peckham 1981).

Outre l'avantage de la portabilité, le Pascal USCD offre la possibilité de regrouper les fonctions et procédures en unités de programme (*Units*) non résidentes en mémoire centrale. Elles sont chargées en mémoire lors de leur évocation par une procédure appelante et libèrent la mémoire dès que leur traitement est terminé. Cette facilité a déterminé la construction modulaire de l'application. Les différentes librairies (fonctions trigonométriques, algorithmes infographiques de base, interface-utilisateur, etc.) et les différentes solutions cartographiques (choroplèthe, isoplèthe, etc.) font, chacune, l'objet d'une ou plusieurs unités de programmes hiérarchisées. Le découpage en unités garantit une utilisation optimale de la mémoire centrale, sans jamais dépasser la faible capacité totale. Le programme principal se résume, quant à lui, à un menu invoquant les unités nécessaires.

D.2. Interfaçage des périphériques et librairies (carto-)graphiques.

L'absence de standardisation des interfaces graphiques rendait les programmes totalement dépendants des périphériques utilisés. Par exemple, telle fonctionnalité, appelée par une fonction et un jeu de paramètres dans le langage graphique DMPL (Houston Instruments), était appelée par une autre fonction et d'autres paramètres dans le langage HPGL (Hewlett-Packard). Dans la configuration qui nous occupe, l'écran graphique disposait d'une petite librairie dédiée, tandis que la table traçante ne bénéficiait d'aucun contrôleur, sinon les 4 codes binaires commandant les deux moteurs pas-à-pas dans les deux sens en abscisse et ordonnée, et les deux codes commandant l'abaissement et le relèvement de la plume (unique) du traceur.

Pour éviter de devoir écrire deux versions des routines graphiques (écran + traceur), et pour offrir un maximum de portabilité sur des périphériques d'autres marques, il a été décidé d'écrire une nouvelle librairie graphique standardisée, en langage Pascal. Tous les algorithmes graphiques fondamentaux, publiés dans les nombreux ouvrages de référence (Rogers et Adams 1976 ; Newman et Sproull 1981 ; Pavlidis 1982 ; etc.), pouvaient être implémentés en Pascal, moyennant le développement de librairies supplémentaires dédiées au traitement mathématique (géométrie, trigonométrie et calcul matriciel en particulier). Les routines de la librairie graphique standardisée sont interfacées avec le périphérique via un contrôleur écrit en langage assembleur appelant trois fonctions censées être toujours présentes avec des paramètres identiques : le déplacement en ligne droite entre deux points, et l'abaissement/relèvement de la plume (faisceau allumé/éteint sur un écran). Dans le cas particulier du traceur Houston DMP2 ne disposant d'aucun contrôleur, l'algorithme de Bresenham a été ajouté au contrôleur pour permettre le déplacement entre deux points, plume haute ou plume basse.

La structure de la librairie graphique standardisée s'inspire des travaux de normalisation en cours à l'époque. D'une part, SIGGRAPH dépose en 1979 *le Status Report of the Graphic Standards Planning Committee*, document de base du comité technique X3H3 de l'ANSI. Ce rapport présente deux normes importantes : VDI (*Virtual Device Interface*) et PMIC (*Programmer's Minimal Interface to Graphics*). D'autre part, le *Deutsches Institut für Normung* (DIN) présente le *Graphical Kernel System* (GKS) qui sera adopté par l'ISO en 1981 (ISO 1982 ; Langhorst et Clarkson 1983 ; Warman 1983). C'est précisément cette norme GKS qui influencera la définition de notre librairie graphique (dessins de symboles, de différents types de traits, d'écritures, etc.).

Le principe des librairies spécialisées, constituant chacune une unité de programme, a été généralisé dans l'application, en particulier pour les routines de base du dessin cartographique. C'est ainsi, par exemple, qu'une librairie est responsable de toutes les procédures liées au hachurage, une autre aux éléments graphiques de l'habillage cartographique ou d'autres encore aux procédures de généralisation et de lissage de courbes. Le principe des librairies cartographiques avait déjà été évoqué dans certaines publications (par exemple : Yoeli 1982), mais peu appliqué dans un environnement micro-informatique suite aux difficultés de gestion de la faible mémoire centrale. Les applications cartographiques proprement dites se contentent, dans notre application, de combiner l'emploi de librairies spécialisées, le plus souvent imbriquées, tout en gérant l'espace mémoire requis pour leur exécution.

D.3. Structure des données géographiques.

Si il y a une chose qui a foncièrement changé depuis le début des années 80, c'est bien la disponibilité de données géographiques numériques – on y reviendra. Seules les agences officielles de cartographie disposaient de données sous cette forme, généralement non accessibles aux utilisateurs extérieurs. Plusieurs publications laissaient entrevoir l'impact qu'aurait la diffusion de données géographiques numériques (par exemple Guptill 1983). Mais en attendant, l'utilisateur souhaitant disposer de données numériques devait les « créer » en numérisant des documents cartographiques.

Notre application devait donc prendre en compte cette étape de numérisation, la tablette graphique Apple faisant office de table à numériser. Comme pour les autres périphériques graphiques, le contrôleur spécifique distribué par Apple a été court-circuité par une librairie standardisée écrite en langage Pascal, responsable de la totalité des fonctions de saisie, d'édition et de géo-référenciation des données récoltées. Couplée à un microprogramme assembleur chargé d'échanger les codes binaires avec la tablette (coordonnées-machine et statut du curseur), la librairie a permis l'utilisation d'autres tablettes graphiques en ne modifiant que le petit contrôleur écrit en assembleur.

Pour garantir la cohérence des données numérisées, une décomposition topologique était imposée dès la saisie. Les nœuds et les arêtes (ouvertes ou fermées, orientées et comptant éventuellement des points intermédiaires) étaient stockés dans des fichiers distincts. Les contours des entités polygonales, simples ou composées, se ramenaient aux séquences des identifiants d'arêtes constituantes. Les différents fichiers étaient organisés sous la forme d'une base de données en réseau. La solution était donc très similaire au modèle POLYVRT et autres modèles topologiques largement discutés à l'époque (Peucker & Chrisman 1975 ; Brassel 1977 ; Kobayashi 1980 ; etc.), mais aussi aux structures géo-relationnelles qui commençaient à être utilisées par les logiciels commerciaux (Atlas*Draw, ArcInfo, MapInfo par exemple). La structure permettait également l'application d'élégantes solutions graphiques (généralisation de lignes, tracé univoque des limites de zones contiguës, etc.) et, en évitant toute redondance inutile de points, elle s'avérait économe en consommation d'espace disque.

Les données attributaires associées aux géométries ainsi stockées, étaient enregistrées et gérées dans des feuilles de calcul aux formats des tableurs commerciaux de l'époque (DIF, SYLK…) ou dans des fichiers texte. Bien qu'elles soient déjà timidement évoquées dans la littérature (Chang et Fu 1980 ; Kobayashi 1980), les solutions consistant à stocker les géométries et les attributs dans une base de données relationnelle étaient encore loin d'être opérationnelles, et totalement exclues de l'environnement micro-informatique du tout début des années 80.

Si la structure topologique offrait de nombreux avantages, elle freinait le traitement cartographique d'entités polygonales simples ou composées et d'entités linéaires composées. D'autre part, les limites de telles entités pouvant contenir un très grand nombre de points, elles risquaient de saturer la mémoire centrale. Pour contourner ces problèmes, lorsqu'une telle entité était invoquée par une procédure, les points formant sa géométrie étaient chargés en mémoire et structurés de façon dynamique selon une liste doublement chaînée. La consommation de mémoire était ainsi sous contrôle du programme et les coordonnées des points étaient disponibles de façon séquentielle pour la procédure appelante.

E. Contributions originales.

L'originalité provient plus de l'architecture et de la structure du logiciel, que des méthodes ou algorithmes programmés. La grande majorité des algorithmes utilisés était publiée et/ou implémentée dans des applications existantes, mais presque exclusivement sur de gros ordinateurs. Plusieurs programmes de cartographie thématique avaient aussi été développés pour micro-ordinateur (Leduc, 1979 ; Langlois, 1982), mais ils étaient le plus souvent dédiés à un type de cartes et à un environnement (matériel, système d'exploitation, langage). L'originalité et la difficulté résidaient donc dans la manière d'organiser les procédures et fonctions en librairies spécialisées, pour obtenir finalement un système portable et ouvert, capable de fonctionner dans un environnement micro-informatique.

La portabilité a été discutée à la section précédente (code P, indépendance vis-à-vis des périphériques graphiques, tant vectoriels que rasters...). L'ouverture, c'est-à-dire la possibilité de développer de nouvelles applications cartographiques en profitant des librairies existantes, est garantie par les interfaces publiques des unités de programmes offertes par le langage choisi. Elles fonctionnent à la manière des API en fournissant les spécifications des procédures et fonctions disponibles dans les librairies.

Au total, l'utilisateur se trouve face à une application unique où, grâce à quelques menus, il peut réaliser plusieurs tâches liées aux activités cartographiques (acquisition, édition, géo-référenciation, généralisation et représentation selon plusieurs types de cartes).

F. Impacts.

Lors de sa présentation, la communication a rencontré un assez vif intérêt auprès des personnes présentes, et quelques semaines plus tard, elle avait l'honneur d'être sélectionnée pour publication dans *Cartographica,* ce qui a élargi son audience. Les réactions et questions apparues durant les mois qui ont suivi AutoCarto Six peuvent être classées en deux catégories:

- celles relatives à l'acquisition, l'installation et la configuration du logiciel;
- celles portant sur les possibilités d'exploitation des librairies en vue d'étendre les possibilités du logiciel (nouveaux types de cartes, etc.).

Les premières étaient de loin les plus nombreuses. Les fonctionnalités de saisie de données avec topologie semblaient les plus appréciées. C'est que l'acquisition de données au départ de cartes papier constituait, à l'époque, un véritable goulet d'étranglement dans la filière de cartographie numérique. L'opération réclamait un périphérique dédié et une interactivité continue, deux choses rarement rencontrées dans l'environnement centralisé des gros ordinateurs et, par contre, parfaitement adaptées à des environnements micro-informatiques. À l'opposé, il existait des alternatives pour les programmes dédiés à tel ou tel type de cartes qui pouvaient se satisfaire d'un traitement différé par lots (*batch*).

Les programmes-sources ont été distribués en une douzaine d'exemplaires un peu partout dans le monde, et nous avons personnellement participé à l'installation du logiciel au sein de plusieurs départements dans les universités voisines.

À partir du milieu des années 80, la portabilité de l'application était sérieusement remise en cause par le succès de l'IBM PC et du système d'exploitation Microsoft DOS. La structure de l'application n'était pas concernée mais l'utilisation du code P et de ses unités de programmes devait être abandonnée au profit d'un autre langage. Parallèlement, l'évolution du matériel (capacité mémoire, affichage en couleurs, etc.) modifiait les contraintes et les possibilités des applications cartographiques.

G. Les innovations et les concepts précurseurs.

Plusieurs hypothèses de travail énoncées en 1983 se sont avérées fondées.
Le micro-ordinateur, seul ou en réseau, client ou serveur, constitue bien la base de toute configuration informatique actuelle. Rares sont les traitements requérant aujourd'hui l'usage d'une configuration informatique lourde et spécialisée, en particulier dans le domaine de la cartographie et de l'information géographique.

Une conséquence immédiate de la suprématie des configurations micro-informatiques est l'abandon rapide des périphériques graphiques vectoriels, au profit des écrans, imprimantes ou scanners, utilisant une technologie raster. La structure des librairies graphiques indépendantes des périphériques et la rasterisation réalisée à la volée pour la visualisation sur l'écran de l'Apple II s'inscrivaient déjà dans cette mouvance technologique.

La portabilité et l'interopérabilité sont devenues la règle, tant pour le déploiement de données, que pour le développement de processus et de services. En matière d'information géographique, c'est même devenu le credo de l'OGC (*Open Geospatial Consortium*). Parallèlement, la diffusion de codes-sources sous licences libres (*Open Source*) ne constitue plus une attitude marginale, mais participe pleinement au foisonnement de solutions informatiques professionnelles.

L'intégration de traitements de données (édition, géo-référenciation, généralisation, etc.) dans une application conçue pour la cartographie ne constituait qu'un timide premier pas vers les progiciels SIG où des traitements de plus en plus diversifiés – d'analyse spatiale entre autres – allaient prendre le pas sur les procédures de cartographie.

Enfin, le recours à un système de gestion de base de données (en réseau) conservant les éléments topologiques des données géographiques est resté le modèle dominant de structuration des données spatiales durant plus d'une décennie pour l'ensemble des logiciels de cartographie et de SIG.

H. Ce qui n'avait pas été présagé en 1983.

Grâce à l'autonomie qu'elle offre, le succès de la micro-informatique avait été pressenti. Par contre, l'interactivité et l'interfaçage "WYSIWYG" généralisés par les systèmes d'exploitation tels que Mac OS et Windows n'étaient pas attendus. Il s'en est suivi une prédominance des périphériques écran - clavier - souris, reportant tous les autres périphériques graphiques au rang de "copies d'écran". L'importance de la visualisation sur écran s'est trouvée renforcée par la rapide évolution de l'affichage en couleurs. Parallèlement, la croissance des capacités des micro-ordinateurs (vitesse, mémoire...) a permis une visualisation dynamique. Ces innovations étaient susceptibles de modifier assez considérablement les applications cartographiques, même si l'on doit constater que, dans l'ensemble, les solutions cartographiques proposées aujourd'hui se contentent souvent de reproduire les solutions classiques, agrémentées de quelques facilités liées à l'interactivité.

Une autre innovation technologique qui n'avait pas été prise en compte est le développement des réseaux, et en particulier celui du réseau des réseaux : Internet. C'est lui qui va permettre la dissémination des données, et par là, leur standardisation, ainsi que l'apparition de services dédiés à l'information géographique. Vis-à-vis des conditions de travail décrites en 1983, la distribution d'informations au départ d'infrastructures de données spatiales supprime presque complétement le recours aux tâches fastidieuses et aux sources d'erreurs liées au processus de numérisation de cartes papier. Par contre, elle réclame de l'utilisateur la maîtrise de prétraitements cartographiques, tels que la géo-référenciation et la généralisation.

En termes de stockage et de gestion de données, le rôle des systèmes de gestion de bases de données (SGBD) s'est considérablement renforcé, mais en changeant complétement de modèle. Du modèle hybride géo-relationnel, on est passé au modèle intégré relationnel ou objet-relationnel, considérant désormais la géométrie comme un simple attribut dans les tables des entités spatiales.

Enfin, la modification la plus sensible pour l'ensemble de la communauté des utilisateurs réside certainement dans l'abandon pur et simple du développement et de la commercialisation de logiciels de cartographie, au profit de logiciels-SIG. La géo-visualisation y est omniprésente, mais les représentations cartographiques thématiques ne constituent plus qu'une fonction optionnelle du logiciel. Sont privilégiés : l'interface transactionnelle avec le SGBD, les procédures d'algèbre de cartes et les traitements d'analyse spatiale. La cartographie analytique, préconisée par certains auteurs (Tobler 1976 ; Clarke 1987 ; 1995), relève plus de ces procédures que de la cartographie thématique originelle.

I. Conclusions.

Les titres et sous-titres de la communication faite à AutoCarto Six en 1983 conservent une connotation très actuelle, tant en matière de développement informatique en général que, de façon plus précise, en matière d'information géographique. Micro-informatique, portabilité, ouverture, base de données spatiales, etc. sont autant de concepts qui permettent d'identifier les propositions originales de l'époque, et de les rapprocher des concepts analogues prévalant aujourd'hui.

Pourtant, cela ne peut cacher ni l'écart considérable de technologie, ni surtout le déplacement du centre d'intérêt des utilisateurs des données géographiques.

- La prévalence de l'écran – de technologie raster – parmi les périphériques graphiques, la gestion de la géométrie des objets géographiques dans les tables d'un SGBD relationnel, l'émergence des services spécialisés sur le Web sont quelques exemples des changements technologiques qui sont intervenus.
- La disponibilité de données géographiques normalisées au sein d'infrastructures de données spatiales, la capacité de localisation embarquée par toute une série d'appareils (véhicule, téléphone, caméra, etc.), la faculté d'afficher, dans n'importe quel navigateur Internet, fonds de cartes, photographies aériennes et images satellite couvrant la majorité de la surface terrestre, sont autant de facilités permettant à tout utilisateur de s'approprier l'information géographique.

I.1. Constats.

Après 30 ans, et malgré l'évolution technologique considérable, on constate que les règles présidant à l'élaboration des cartes thématiques ont peu changé.

> On se doit pourtant de mentionner les travaux remarquables sur l'usage de la couleur qui – même si cette variable graphique n'est pas encore utilisée pleinement – ont sensiblement fait évoluer la sémiologie graphique (Brewer, 2005 ; Garo, 2009).

Il est tout aussi vrai que les types de cartes restent fort similaires à ceux que l'on a toujours connus. À l'exception de quelques formes spectaculaires de visualisation (anamorphoses, anaglyphes…) facilitées par l'informatique, la créativité en matière de cartographie numérique semble s'être essoufflée au milieu des années 80.

> Parmi les causes possibles de cette relative stagnation, on peut avancer l'introduction dans l'environnement micro-informatique d'une couche d'interface-utilisateur conviviale, mais lourde et largement "propriétaire", ce qui a vraisemblablement freiné la créativité en éloignant bon nombre d'utilisateurs des tâches de programmation.

Pour le professionnel, la **géo-visualisation** semble s'être imposée, en lieu et place de la cartographie thématique. Elle est perçue comme l'ensemble des outils et techniques supportant les méthodes d'analyse de données géographiques, grâce à l'usage des capacités interactives des configurations micro-informatiques.

> Couplée aux traitements de données géographiques dans des logiciels SIG, la géo-visualisation offre d'indéniables avantages au professionnel. Pourtant, la représentation graphique « par défaut » des données et des résultats des traitements est souvent aléatoire et par conséquent non signifiante. Si l'utilisateur peut s'en contenter lors de manipulations rapides et multiples, il en va tout autrement lorsqu'il s'agit de communiquer ces résultats à des tiers.

Pour l'amateur, les fonctions associées aux sites de **cartographie en ligne** lui offrent la possibilité de construire et de visualiser des « cartes » personnalisées.

> La consultation des « cartes » réalisées par les profanes accédant à la « géographie / cartographie participative » par le biais des sites de cartographie en ligne montre souvent de telles ambiguïtés et de telles aberrations que ces documents ne sont pas utilisables. On perçoit cependant l'émergence d'une demande d'outils et de règles plus efficients de la part de la communauté d'utilisateurs avertis.

Il n'a jamais été aussi facile qu'aujourd'hui de visualiser l'information géographique, et pourtant une communication cartographique efficace reste indispensable et réclame toujours la même réflexion (Bord, 2012).

I.2. Perspectives.

Les services Web constituent une des innovations les plus importantes de ces dernières années dans le domaine de l'information géographique. Parmi ceux-ci, le WMS (*Web Map Service*) est de loin le plus utilisé. En première approximation, la réalisation de l'image qui est transmise par ce service ressort de la cartographie thématique, sous contrôle de contraintes supplémentaires dues à la nature du canal de communication.

La conception de l'image véhiculée par le WMS est de la responsabilité du détenteur des données géographiques. Cependant, il est possible d'envisager un chaînage de services qui permettrait à tout utilisateur :

- de récupérer, auprès d'un ou de plusieurs producteurs, des données géographiques de base (via un ou plusieurs WFS – *Web Feature Service*) ;
- de les soumettre à des traitements adéquats en ligne (via un ou plusieurs WPS – *Web Processing Service*) conduisant à l'obtention d'une carte thématique ;
- et finalement de créer un WMS sur un serveur, afin de communiquer la carte à d'autres utilisateurs du réseau.

Un WPS qui, toute autre chose étant égale, pourrait sélectionner le type adéquat de carte thématique en fonction des données à traiter, et qui respecterait les règles de rédaction cartographique élevées au rang de standards (sémiologie, écritures, habillage, etc.), constituerait certainement un outil utile tant pour le professionnel que pour l'amateur de cartographie participative. L'exploitation des caractéristiques de la cartographie en ligne permettrait en outre de développer de nouveaux types de cartes.

Parallèlement, l'évolution technologique des dispositifs de visualisation graphique (dispositifs portables, écrans virtuels…) réclame une adaptation rapide des règles et des méthodes de représentation cartographique. Plus fondamentalement encore, l'évolution du concept de géométrie de l'information géographique – notamment selon les règles du langage GML (Donnay 2009) – laisse entrevoir une nouvelle approche des méthodes de la cartographie (de la généralisation à la représentation). Il n'est pas impossible qu'après quelques décennies de stabilité voire d'indolence dans le domaine de la cartographie thématique, les prochaines années voient émerger un nouveau dynamisme, similaire à celui connu au début des années 80, avec l'apparition de la micro-informatique.

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14

LACAD: Looking Back and Looking Forward at Simulating and Visualising the Real World

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ABSTRACT. Thirty Years of research in environmental simulation and visualisation started with a small programming project which integrated computer graphics with plant growth simulation. The compelling demonstration of introducing dynamic spatial-temporal simulation seeded the development of three decades of research which integrates computer programming, environment, modeling and simulation and, ultimately, decision support systems. This paper outlines the evolution of that body of research.

KEYWORDS. CAD, plant growth simulation, simulation, visualisation, GIS, cellular automata, artificial intelligence, intelligent agents, recreation behaviour simulation, RBSIM.

A. Title of AutoCarto Six paper.

LACAD: A Computer-assisted design package for micro-computers

B. Reason for paper.

The development of LACAD (Landscape Architecture Computer- Assisted Drafting) was motivated by the emergence of low-cost personal computers, the emergence of computer graphics, and the desire to introduce concepts in technology that would "value add" to the practice of landscape architecture rather than simply mimic manual processes.

At the time of developing LACAD, personal computer technology was in its infancy. The technology was typified by 8-bit processors, 64K ram, 5mb hard disk, and CPM operating system. There was little off-the-shelf software available and industry standard

CAD systems tended to be expensive engineering systems hosted on mini-computers. This environment required custom software development to demonstrate concepts.

C. Technical and conceptual aspects of LACAD.

LACAD was as much an exercise in learning modular programming as how to integrate data file management with computer graphics. It started simply as a desktop CAD system but, as it evolved, the concept of simulating plant growth emerged.

One of the biggest problems for students, designers, and clients is to visualise the dynamic aspects of planting design. Each plant cultivar will have a different growth rate, a different plant form, and different mature height and width. These variations have an impact on decisions relating to plant spacing, light requirement of plants as trees mature and cast more shade, and long term maintenance of plants such as pruning, removal of crowded plants and of course the composition of the design as plants mature. A typical plant palette for even a small residential design may have a dozen different plants including ground cover, shrubs, trees and vines.

LACAD used simple linear scaling techniques to simulate growth over time. Graphic plant libraries were linked to data files which included the mature height, width and age at maturity. Plants were scaled simply by dividing the mature age by the target time frame and multiplying the result by the height and width recorded for that plan (with the maximum scaling limited to 1.0).

The results were immediately captivating, and the concept of simulation in planting design was immediately embraced by the design community.

D. Impact of LACAD on industry.

Commercial CAD technology on personal computers developed rapidly, and within a year the emergence of products such as AUTOCAD were becoming rapidly adopted my innovative design firms. The industry quickly grasped the value of plant growth simulation, and it was implemented as custom modules to commercial CAD systems. Much of the development work required the development of good plant libraries and more sophisticated equations for more accurately simulating growth rates of different plants.

E. Implications and motivations for future research.

As the concept of plant growth in CAD environments was quickly adopted by industry, there was little motivation for continuing development of LACAD, so the project was dropped and our attention moved to other prospects for developing concepts of simulation and visualisation in environmental applications.

Error! Reference source not found. summarises the evolution of research over the past 30 years. Each research project shows the integration of technology, the innovative aspects of the research, the subject of simulation and visualisation, and the underlying theory behind the research.

The following sections briefly recap each of these projects.

Table 1. Evolution of simulation and visualization research in environmental applications

Project	Technologies	Innovation	Simulation and visualisation	Theory
LA CAD	Computer graphics	Use of computers to simulate plant growth within the context of planting design	Plant growth	Linear growth over time
	Stored data			
	Plant growth equations			
SAGE	Raster GIS	Advancements in map algebra and viewshed analysis	2d and 3d map visualisation	Tomlin's map algebra
Geographic Cellular Automata	Raster GIS (SAGE)	Application of cellular automata theory to GIS	Spatial simulation through time	Cellular automata, map algebra
	Iterative programming for GIS			
Artificial Intelligence	Neural networks	Use of AI in natural resources management		Neural networks
RBSim	GIS	Integration of GIS and Intelligent agents to simulate recreation behavior	Spatial intelligent agents	Autonomous rule-based agents
	Intelligent agents			

E1. Raster GIS and cellular automata.

SAGE (Itami and Raulings 1993) is a raster GIS that is an implementation of Tomlin’s Map Algebra (Tomlin 2012), with enhancements for 2D and 3D computer graphics display of maps. Analytical enhancements included development of improved methods for intervisibility (viewshed) analysis and extensions to map algebra (Itami 1995). SAGE was developed primarily as a teaching tool, but more importantly provided a research platform for developing concepts for dynamic land use simulation using cellular automata theory.

Cellular automata (CA) theory is a captivating concept popularized by Conway's "Game of Life" (Gardner 1970). The obvious parallels between Conway's Game of Life and raster- based GIS such as SAGE were explored (Itami 1988; 1989; 1994; Itami and Clark 1992) with suggestions for further extending GIS scripting languages to include iterative programming in order to support CA simulation theory within GIS. The concept has been advanced by the research community world-wide, and integrated into a number of spatial simulation and modeling platforms for urban and natural resources modeling and simulation.

E2. Artificial intelligence in natural resources management.

For some time, natural resource managers have faced the complex task of understanding human-landscape interactions and associated use patterns in dispersed settings. And that already difficult challenge is further complicated by the subsequent synthesis and modeling of the behaviours that affect such patterns of use. That is, individual and aggregated human behaviour has cumulative impacts affecting the integrity of the environment, and the experience of other individuals who share the same setting.

Modeling such human use patterns in natural settings rose to the forefront of natural resource management research. The problem became a matter of discovering and representing the dynamic interrelationships between these two complex and interrelated variables.

While conventional approaches have limited use in acquiring information about and understanding of such complex associations, artificial intelligence (AI) techniques for capturing spatial/dynamic rules of behaviour coupled with geographic information systems (GIS) and spatial simulation models have evolved into standard practice among land management agencies. Simulations provide a mechanism to develop and experiment with artificial models of human use patterns not conventionally employed by either the expert or statistical approaches. Because the parameters of the model can be adjusted independently in a series of simulation runs, the data produced by testing out various management options are often easier to interpret than those from real systems.

All this simulation capability became possible with the development of AI-based technologies that emerged in the 80's to enhance the tools used to process spatial data, particularly as they related to human-landscape interactions. When combined with the data storage and processing capabilities of GIS, artificial intelligence tools promised to provide the field of resource management with new analytical and modeling capabilities.

This merging of technologies did not disappoint. Successful connections were developed between GIS and a variety of artificial intelligence- based packages including Artificial Neural Networks and Genetic Algorithms. Neural nets were revisited in the early 1980's by a number of researchers who developed more advanced multi-layered networks which overcame the criticisms put forth by Minsky and Papert (1969) and Openshaw (1993).

Since that time, neural network research has progressed steadily. The development of commercially available, user- friendly neural net packages in the late eighties led to an explosion of studies which investigated their utility in a wide variety of applications of suitability analysis, including, for example: forest management (Gimblett *et al.* 1994; 1995); vegetation classification and assessment (Deadman and Gimblett 1997); landscape perception (Gimblett 1990); forest change (Guisse and Gimblett 1997; and, Gimblett and Ball 1995). Imperative to that work was the seamless connection between these artificial intelligence techniques linked to GIS.

The need to develop a comprehensive and empirically- based framework for linking the social, biophysical and geographic disciplines across space and time became a driving force behind our research in the late 90's up until present day. Itami and Gimblett (2005) and a further refined version by Gimblett (2005), outlined a decision framework that incorporates human use simulation modeling as a method of bridging a significant social science knowledge gap to improve the ability of decision making to positively and proactively manage human-land use interactions. This approach uses spatial agent-based modeling as a foundation for studying human landscape interactions across space and time, and is carefully integrated into a planning and management framework.

As a result of the experience of using artificial intelligence approaches to aid in capturing human knowledge and behavioural rules, and GIS-based spatial algorithms to provide the landscape and spatial functions, our modeling platform began to take shape. This development work also included employing modeling protocols for generating confidence intervals through the exploration of the number of replications for spatial terminating simulations (Itami *et al*. 2005).

In order for formalize our thinking on agent-modeling, we developed our own software referred to as RBSim (Recreation Behaviour Simulator) in 1996 to provide managers of outdoor recreation a new tool for understanding the spatial/temporal behaviour of pedestrians and vehicles on crowding, visitor facilities, safety, and visitor experience. RBSim is an integration of GIS and Intelligent agents to provide a simulation platform which provides managers with a simulation and visualisation of the movement of visitors, vehicles and vessels with statistical reports of visitor numbers, density, and speed at specific locations at different times of the day, week or season.

Our simulation work using RBSim has taken us on a journey around the world studying human use patterns in places such as the Coconino National Forest, Arizona, John Muir/Ansel Adams and Dinkey Lakes Wilderness in California (Lawson et al, 2005), Prince William Sound (Wolfe *et al.* 2008) and Misty Fjords Alaska (Gimblett *et al.* 2005b), Canada's Mountain Parks, Banff, Canada (Itami *et al.* 2008), Salmon-Challis National Forest (Gimblett *et al.* 2005a) and Joshua Tree National Monument (Murdock 2009), Port Campbell National Park in Australia (Itami 2005) to river recreation issues in the Grand Canyon National Park (Gimblett *et al.* 2005c) and Melbourne's Waterway, Australia (Itami 2006). We have learned many lessons along the way, with each application providing insights into more sophisticated data collection methods, field-based studies, and more complex and larger scale simulations and visualisations.

From the evolution of our applications and especially using our agent-based work, we have learned that simulations can provide:

- A comprehensive and dynamic understanding of human behavior, interactions between humans and their environment;
- A framework for a more holistic and comprehensive way of incorporating human landscape information into the planning and management process;
- A way of measuring human interactions that are difficult or expensive to do in the field;
- A way to test alternative management scenarios and place planning and management into an exploratory and experimental framework;
- Communicating complex inter-related issues in human-landscape management to the public and decision makers;
- A comprehensive framework for human monitoring, understanding human use patterns, and as a decision support system for defining and testing alternative management responses to changing conditions.

F. Conclusion: From small ideas big ideas grow.

30 years ago, we began a collaboration that continued a theme of exploring the use of computer technology for simulation and visualisation of the interaction of human decision making and behaviour with environment. The desire to understand the dynamics of human social systems and environment has been the core idea driving the research, and has resulted in efforts that have had direct impact on other research and on design and management practice. The integration of simulation and management decision making still drives our research, and will continue into the foreseeable future.

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15

Adaptive Grids Then and Now

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ABSTRACT. The adaptive grid (now called the uniform grid), an algorithm for efficiently finding intersections in large geometric databases, was introduced in the 1983 paper. The cross-fertilization from computer graphics and geometry to GIS and automated cartography has continued to be useful and, as discussed, is even more relevant with current large databases and fast computers.

KEYWORDS. Adaptive grid, uniform grid, efficient automated cartography algorithms, large databases.

A. Title of AutoCarto Six paper.

Adaptive grids for geometric operations.

B. Reason for paper.

The intent of the 1983 presentation was to introduce a new, efficient geometric data structure to facilitate certain important spatial operations on large (for that time) GIS datasets. One such operation was to find all intersections among a large set of small line segments. A second was to find which polygon of a large planar graph contained a test point. These operations are necessary components of common operations such as map overlays. The broader goal was to link the computer graphics and computational geometry communities to the GIS and automated cartography communities, and to show that each community had something of use to the other.

C. Thoughts shaping the design of the 1983 paper.

This paper was driven by my non-geographer's perspective on GIS and automated cartography. Although I had worked with geographers (such as David Douglas at the University of Ottawa) since about 1969 during summer jobs while I was a high school student, my own background was in computer science and computer graphics, based on a love of classical geometry. The beauty of classical geometry lies in the multitude of implicit relations between points and lines that follow from a few Euclidean axioms. Indeed, my current, long-term unsolved problem of trying to find a mathematics for terrain rests on that philosophy.

In the summer of 1972, between college and grad school, I worked with Douglas in Tom Poiker's lab at Simon Fraser University. There, I designed and implemented the first triangulated irregular network program in geography. (Unfortunately, being an undergrad, I knew nothing about publishing. I gave the lab my documented Pl/1 code with examples, and even a primitive animation of the triangulation being incrementally refined as new points were inserted. However I didn't write a paper for publication.)

Next, as a grad student at Harvard, while enrolled in the computer science program in applied mathematics in the Division of Applied Science, I worked in the Lab for Computer Graphics and Spatial Analysis in the Graduate School of Design (the architecture school) in Gund Hall. After graduation, I joined the faculty of the Electrical, Computer, and Systems Engineering Department at Rensselaer Polytechnic Institute. I'm still here.

The common thread in these experiences is a liking for solving geometry problems. A research theme in computer science, then as now, was to find techniques (algorithms) to solve problems on larger datasets in less time. However, the exact time used was not of interest, but only the rate of growth of the time as the dataset got larger. (The reason is that exact times shrink as hardware gets faster, but the rate of growth stays the same, and so the rate of growth expresses something more fundamental about the algorithm.)

However, computer scientists sometimes carried this theme too far, because actual times are important in the real world. Here, solving a problem in half the time or space, although of no theoretical interest, is important for practical reasons. Indeed, computer scientists have more than once ignored cartographers' practical solutions to real problems, because those solutions were not sufficiently theoretically interesting. The exceptions that do exist benefit both fields.

Likewise, in GIS and automated cartography there is a contrast between theory and practice. Grand system designs are all well and good. However, taking them from abstract exercises to concrete useful implementations requires expertise in computer science on how to create efficient algorithms and data structures. Conversely, GIS and automated cartography give computer science a set of important problems to solve.

My paper was intended to extend the bridge between these separate communities, by providing an efficient solution from computer science to an important problem in automated cartography.

D. Derivative attributions.

In computer science, there was the new field of computational geometry, first named by Michael Ian Shamos. His unpublished PhD thesis (Shamos 1978) was inspirational to many, and resulted in the influential book (Preparata 1978). (The term *computational geometry* has also been used to name two other fields in computer science, which are irrelevant to this paper). There was also efficient computational geometry work by Franco Preparata, and Jon Bentley (1979), whose work was both inspirational and practical.

The group at the Harvard Lab for Computer Graphics and Spatial Analysis (LCGSA), led by Alan Schmitt, and including Nick Chrisman, Jim Little, James Dougenick, Geoff Dutton, Scott Morehouse and others, was also busy designing new algorithms and producing the widely used Odyssey suite of software, (Harvard 1976). Interestingly, no one had a PhD, and the lab, situated in the Graduate School of Design for want of a better place, seemed to be unwanted by Harvard, (Chrisman 2006).

In the late 1970s and early 1980s, the LCGSA hosted several influential conferences, whose proceedings are almost impossible to find today, (Harvard 1979, 1980, 1982, 1983).

While enrolled in computer science but working in the LCGSA, I basically created my own research theme, developing the ideas presented in my paper for my PhD work, (Franklin 1978). I am grateful to Harry Lewis, my advisor, for permitting such an unusual arrangement.

E. Original contribution.

The original contribution was of a data structure that is so simple that people cannot believe that it can be useful. On first seeing it, the common reaction is that it's nice, but to be useful has to be complexified into something like a quadtree. That's wrong! Both theoretical analysis and experiments on real data support this argument put forward.

F. Impacts.

The adaptive grid technique, now called the uniform grid technique, has stood the test of time, and is increasingly useful today. Applications can use it to process hundreds of millions of objects. It also utilizes parallel computers quite well. That ability was apparent from the start; it's just taken a while for the available hardware to catch up to the technique. Now, every computer with an NVIDIA graphics card can do useful parallel programming.

As discussed by Akman (1989) and Franklin (1984, 1988, 1989a, 1989b, 1990a. 1990b, 1994, 1999, 2000, 2005a, 2005b), uniform grids have been used to solve problems such as the following:

1. Preprocess millions of fixed points so that the closest fixed point to a new query point can be found fast.

2. Preprocess a large planar graph (i.e., a map) so that the polygon containing a query point can be located fast.

3. Overlay two maps to find the areas of all the nonempty intersections between a polygon of the first map and a polygon of the second. One application is the cross-area problem, to interpolate some statistic that is known for each polygon of the first map onto each polygon of the second.

4. Find the volume of the union of many polyhedra. One application is object collision detection. (If the union volume changes as the objects move, then they just collided.)

The general philosophy of simple and efficient solutions has been successfully applied to other problems such as the following.

1. Siting multiple observers on terrain so as to maximize the union of their viewshed polynomials (Franklin 2011).

2. Interpolating from contour lines to raster elevation data (Gousie 2005).

3. Computing the hydrography on massive raster terrains (Magalhães 2012).

4. Filling gaps in incomplete hydrography in a geologically reasonable way (Lau 2013).

G. What was new in the paper?

The novel aspect of the paper was the publication of a technique that had been devised to solve a problem in computer graphics, but which could also solve important problems in automated cartography.

H. Conclusions/Findings/Next Steps.

Bridging computer science and GIS/automated cartography to devise efficient algorithms is as important as always. New problems needing efficient solutions on the new faster parallel computers continually appear, because of the ever larger databases of geographic data that need to be processed.

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Fractals in Context: Fractal Enhancement for Thematic Display of Topologically Stored Data

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ABSTRACT: This paper provides an assessment of the intellectual milieu in which the original AutoCarto Six fractal enhancement paper was conceived, explains some of the key challenges that were addressed and attempts to place the contribution into a current research context.

KEYWORDS: Fractals, cartographic lines, generalization.

A. Title of AutoCarto Six paper.

Fractal enhancement for thematic display of topologically stored data.

B. Introduction and background.[1]

The basic ideas underlying the use of fractals in geography, such as scale dependence and self-similarity, were not new at the time of the 1983 AutoCarto Six conference (Steinhaus 1954; Richardson 1961; Perkal 1966; Mandelbrot 1967). And our paper Armstrong and Hopkins 1983) was not especially remarkable, except that it represented a departure from the mainstream focus of digital cartographic line processing, given our concern with *enhancement* of detail, rather than generalization, and our application to stream networks, rather than polygon boundaries. Perhaps that is why, according to Google Scholar, the paper has been cited only six times; or perhaps not.

The presented paper did, however, generate considerable debate at the conference since a paper scheduled to follow it was cancelled, thereby providing an additional twenty minutes for discussion. The central theme of the debate that ensued was

[1] The authors collaborated extensively on the paper presented at the conference. The use of the first person in this retrospective report refers to discussions related to the implementation of the Fortran code used to perform cartographic line processing.

whether our attempt at enhancement was a legitimate scientific task with a solid epistemological grounding.

Fractals were in the air in the early 1980s subsequent to the publication of Mandelbrot's two lavishly illustrated books on the topic (Mandelbrot 1977, 1983). Mike Goodchild had written a paper in which he used fractal concepts (1980) and then Geoff Dutton (1981) published a fractals paper, mostly focused on coastlines and political boundaries, that appeared in *The American Cartographer* (now *Cartography and Geographic Information Science*). Geoff's paper clearly demonstrated the potential of fractal enhancement and was published, for us, at a most propitious time, as we had been discussing the development of a mapping capability for the Illinois Streams Information System (Hopkins, Armstrong and Belford 1981).

Remember that in the early 1980s digital storage, transmission, and search, as well as graphic capture and display, were all either limited in capability or extremely expensive. It was clear that we were not going to digitize, at considerable labor and storage costs, a high resolution representation of the entire hydrological network of Illinois. The project wasn't budgeted for that task and a detailed (and scale dependent) cartographic representation would not have supported the designed functions of the system, which relied on the use of scale-free topological relations among stream network elements and distances, measured along streams on annotated USGS 1:24000 topographic maps (Hopkins and Armstrong 1985; Armstrong and Hopkins 1991).

What we did have, however, was a nearly free, very low resolution representation of streams: the centroids of each USPLS section (roughly 2.6 sq km) through which a stream flowed. This centroid data was available from an existing database called ILLIMAP (Swann *et al*. 1970). The question was: Could we credibly use this low resolution data to produce thematic maps of fluvial phenomena?

C. Approach and contributions.

A substantial amount of conceptual and empirical research had been done, or was in process, relating to cartographic lines (Peucker 1975), though the vast majority of the work was related to generalization processes such as simplification (Douglas and Peucker 1973; Jenks 1981; McMaster 1983). This was the exact opposite of what we needed. Lew attended a conference of the American Society of Landscape Architects and while he was away, Dutton's article arrived in the mail. I read it immediately and decided that this was an appropriate path to explore. When Lew returned from the conference, he came to my office and told me he had talked to a colleague who had offered a suggestion about our problem. Before he could explain, I said "fractals" and Lew's jaw dropped. We were both astonished that we had arrived at the same place via very different paths. Perhaps it was a type of intellectual kismet.

I wrote to Geoff, who generously sent me a copy of the FORTRAN code he had written for his article, which I entered, compiled and executed on a CDC Cyber 175 system connected to a Tektronix 4012 via a 1200 baud modem. I also implemented several subroutines from David Douglas's (1974) gem: "Collected Algorithms", the most important of which was the eponymous "Subroutine Wiggle".

In addition to the relatively straightforward introduction of sinuosity into the low resolution coordinates, other processing needed to be performed to make the results appear realistic. Since the centroids of the approximately 2.6 sq km cells were the starting material, individual streams could flow into and out of and then back into cells, and thereby appear to form peculiar-looking spikes and closed loops that did not exist on the ground (with apologies to Bob Dylan, you don't need to be a fluvial geomorphologist to see this problem).

These "features" had to be detected and corrected using inchworm algorithms that would crawl along the lines and discover duplicate points that would signify topological flaws in the network. However, there was no theoretically specified "look ahead" (or linear window) for these algorithms, so a considerable amount of computation was required to ensure that errors were eliminated.

Another problem occurred because two (or more) different streams could each enter into a section and either leave or merge their flows. If they flowed back out of the section, spurious topological connections were established that required correction.

A final difficult problem was discovered when we wished to plot information about what was on the left and right banks of each stream segment. This appears to be a straightforward geometrical problem, until you consider what happens when you try to create simulated banks for sinuous lines: the banks will loop back on themselves. Or when you consider what happens at stream confluences: the banks will intersect at most plotting scales. One solution, of course, is to shorten the banks relative to the stream centerline and plot results proportionately.

D. Envoi.

At the conference, other papers with fractal or fractal-like subject matter were presented, the most notable one being by Shelberg, Moellering and Lam (1983). It is not clear what Mark Shelberg or Hal Moellering, a distinguished analytical cartographer, did with fractals in subsequent years, but Nina Lam went on to "write the book" on the general topic (Lam and DeCola 1993).

During the last two decades, interest in fractals has declined. Researchers have clearly discovered other interesting and related properties of complex systems, such as the emergent behavior (Holland, 1998) exhibited by dynamic systems (e.g., in agent based models) and have moved on to explore other themes in their research.

Even so, the scale dependent nature of digital cartographic lines makes them fair game for further research activity (e.g., Buttenfield and McMaster 1991). It is our hope that our small contribution will spur additional activity by researchers who wish to learn more about the wonders of digital cartographic lines.

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Soil and Agricultural Land Maps – From Mapping to GIS

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ABSTRACT. In the late 1970s and during the 1980s, IGN France developed and processed an innovative digital cartographic production line that was specially designed for thematic mapping, and experimented with the use of digitized soil and agricultural land data in a geographic information system perspective. However, the technology, which was appropriate for a specialized organization with high-level computer experts, was too complex to be expanded to the potential users of the system.

KEYWORDS. Thematic mapping, raster data, operational production line, geographic information system.

A. Title of AutoCarto Six paper.

Carte des sols et carte des terres agricoles.

B. Introduction.

The paper delivered – in French! – during the AutoCarto Six Conference under the title "Carte des sols et carte des terres agricoles" ("Soil and agricultural land maps) was one in a series of papers presenting IGN France's achievements in building and operating a cartographic system primarily designed for graphic plotting, and enriched by its designers for digitizing cartographic data and for plotting films for map printing. A selection of papers describing this work is presented in the References section.

In addition to the core graphic system, IGN's experts designed their own software to manipulate and combine digital data in both vector and raster formats, and to propose new ways and outputs to use those digitized cartographic data.

C. Reason for paper.

At the time the paper was presented, the French ministries in charge of environment and agriculture had launched two mapping projects: a land-use inventory of coastal areas at 1:25,000, and a map of land potentialities for agriculture at 1:50,000. In both cases the anticipated end products were printed maps intended for technicians in land planning, environment protection, tourism development and farming on the one hand, for decision-makers on the other hand.

As compared to a traditional mapping process, the original idea we had in IGN was to create not only a digital image of the maps, but a set of files and ancillary data as digital products in themselves, being at the same time steps or tools in the process line resulting in printed maps, and base information for further and additional uses – specifically computation of statistical data on land use or potential values, and provision of an initial coverage for diachronic series and change assessments.

D. Thoughts shaping the design of the paper.

The paper was designed to first describe the cartographic process line, and the type and variety of information used by soil experts to define soil categories and potentialities. That discussion provided the appropriate background to understand the comprehensiveness of collected information, and to imagine what could be done from the cartographic database which had been completed. Furthermore, the paper discussed how it could be done in an operational environment, i.e., not only for test or study areas, but for full coverage of a country or of a significant part of a country.

Then the paper described the way the data were processed to prepare derived maps appropriate for decision-making, and to compute a database with the surfaces of soil or land-use categories per natural areas or administrative units. Finally, it considered the potentialities of such projects.

E. Derivative attributions.

The 1983 paper benefited from the original experience in raster data processing, and in raster-to-vector and vector-to-raster conversions which had been acquired and operationally used since 1978 in IGN's thematic cartographic division from its own designs and developments. It demonstrated the capability for undertaking thematic map coverage, and structuring cartographic data on large areas to re-use them over time.

F. Original contributions.

The original contribution through the soil and agricultural land map project was the design and implementation of an early digital cartographic process line, not only for drafting maps from scientific data, but in considering the scientific data as high value information with various possible applications.

Although the process line was certainly rather sophisticated and required strong expertise, with a succession of operations either in raster formats or in vector formats on two different and totally separate computer systems, we can consider the project as the creation of an actual and operational geographic information system.

Further, the overall design was that of an information system in itself, before the stage of technical implementation, as compared to assembling existing tools in a better way but with their inherent limitations.

G. Conclusion.

The conclusion is a paradox: the design was effective – i.e. the map series was produced and the databases were built up – but the move from a cartographic system or process line to a geographic information system failed. I see two main reasons for the failure.

The first one is mainly a technical reason. Our databases were built according to our own internal structure models, which were optimized for several time-consuming processes. However, this work was being done when there was a lack of standards. We only could use our internal software and our computer experts to process the data, and to experiment with new ideas. Moreover, and later in the work program, no commercial geographic information system had been developed for processing raster databases in easy ways.

The second reason is of an organizational and maybe systemic nature. We had within IGN very good experts in mapping, cartographic information processing, and computer science, but the experts in soils and agriculture were in other organizations, they were not computer experts and, at that time, they could not directly operate the first geographic information systems that were easily available on the market.

The potentialities of the project were impressive, but in retrospect, the overall plan was a little too advanced for the technology to be actually accessible to users.

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18

Fractals 30 Years After: A Retrospective of "Measuring the Fractal Dimensions of Surfaces"

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ABSTRACT: Thirty years ago, it was hard to imagine the long lasting impacts that this paper had on the rather new concept of fractals applied to the cartographic field. Based on work by Goodchild using the isarithm algorithm, an interactive program was developed that computed fractal dimensions of surfaces from a variety of perspectives and sampling distances. Over the years, this has led to subsequent research, particularly by Lam and a host of others, noting how inseparable fractals are from scale. Despite significant advance, the challenges remain almost the same as they were thirty years ago: measurement sensitivities related to scale, sampling size and sampling direction, and as noted by Lam, reconciling different results from different measurement methods. Over the years we have witnessed a multitude of fractal related research and no doubt this paper helped originate this research and certainly led to improved methods to understand the complexities of surfaces as part of the milieu of analytical cartography.

KEYWORDS. fractal measurement, ICAMS software, local fractals, texture measures, analytical cartography.

A. Introduction.

Thirty years have passed since we published the paper "Measuring the fractal dimensions of surfaces" in *Auto-Carto Six* in 1983. During the early 1980s, the concept and applications of fractals were very new to many fields. Mandelbrot's first book on fractals was published in French in 1975; it was translated into English in 1977, followed by his second book published in 1982 and translated in 1983 (Mandelbrot 1977, 1983). The publication of Mandelbrot's books generated enormous interest in fractals from researchers in every major discipline, ranging from Physics to Music. Fractals were literally everywhere in the 1980s and 1990s (Barnsley 1988).

Researchers in cartography and GIS were among the earliest in developing algorithms and applying fractals in the field (Goodchild 1980; Lam 1980; Dutton 1981). The authors of this paper were among the first few groups of researchers who conducted research on fractals. In fact, the 1983 paper was a sequel to another paper published in *Auto-Carto Five* in 1982, which focused on the fractal measurement of curves (Shelberg *et al*. 1982). Both papers were written while Shelberg was a cartographer at the then Defense Mapping Agency (now National Geospatial Intelligence Agency) but was on leave to pursue a master degree at the Ohio State University, and Lam and Moellering were faculty members at that time. Both papers were based on Shelberg's master thesis research. This background context information is relevant to understand the contributions and impacts of the 1983 paper, which include impacts to both academic and non-academic sectors, as summarized below.

B. The contributions.

The 1983 paper documented a new algorithm developed in Shelberg (1982) to measure the fractal dimensions of surfaces. The algorithm was tested by using two samples of fractal-generated surfaces; the shear-displacement algorithm developed by Goodchild (Goodchild 1980; Lam 1980) and one real elevation surface. The results showed that the algorithm was robust and was able to capture the complexity of the surface and yield fairly accurate fractal dimension values. The paper concluded that the algorithm could serve as a new means to measure surface roughness, a new means to measure the amount of cartographic generalization, and a new method to store a compressed surface.

The ideas and methods contained in the paper were very new and original. We consider that the paper contributes to three aspects. First, the new algorithm was based on the algorithm originally developed by Goodchild (1980) but it extended the original one to include measurement of surfaces that are not strictly self-similar. In Goodchild's algorithm, only the average contour line (i.e., isarithm) was used to derive the fractal dimension of the entire surface. Since Goodchild's study only dealt with self-similar surfaces, using an average contour line is reasonable and sufficient to represent the fractal dimension of the entire surface. However, many real-world surfaces are not strictly self-similar, hence the new algorithm was developed to allow the measurement of a range of contour lines derived from the entire surface and then use the average dimension value of all contours to represent the entire surface. While many algorithmic modifications are typically made to improve computational efficiency and robustness, the modification made in this paper implies a major theoretical departure from the original definition of fractals, which is to relax from strict self-similarity to statistical self-similarity. Hence, the paper is considered one of the first attempts to incorporate statistical self-similarity, which has made the original fractal concept more applicable and accessible to a wider range of phenomena.

Second, the algorithm was implemented in an interactive mode, allowing the user to experiment interactively with different parameters and compare the resultant dimension values. This interactive measurement system was considered innovative in 1983, as interactive computing with user-friendly interface for cartographic research was still uncommon.

Third, the use of fractal-generated surfaces to test different cartographic algorithms was also creative. Although the same approach of generating fractal surfaces had been used to test the accuracy of spatial interpolation methods (Lam 1980), the adaptation of the shear displacement surface algorithm from one computing platform to another was a challenge and time-consuming when at that time mainframe computers with limited input/output access were the only mode of computing for our research.

C. The impacts.

While the fractal model is fascinating and has been applied widely, the use of the fractal approach in modeling and measuring complex spatial phenomena has been subject to a number of criticisms (Lam 2009). First, using a single fractal dimension index to describe complex spatial phenomena runs the danger of oversimplification. Second, self-similarity, the core characteristic of fractals, only exists at certain scales of many phenomena. Therefore, fractals and scales are inseparable, and concepts such as multi-fractals or local fractals had since been developed to capture the complexity of spatial phenomena at different scale ranges (Lam and Quattrochi 1992). Third, the measurement problem remains, as different researchers use different approaches, leading to inconsistency of the measurement results. Moreover, reliable software for computing fractals was not available.

Following the 1983 article, we continued working on fractals to address these important issues. Some of the impacts and achievements include: (1) First, ten years after *Auto-Carto Six*, Lam and De Cola (1993) co-edited the book "*Fractals in Geography*", which documented, at that time, the most current research and applications of fractals in physical geography, human geography, and mapping sciences. In addition, the book contains four chapters describing the basis of fractal theory, fractal measurement, fractal simulation and interpolation, and the fractal paradigm in geography. Algorithms for computing fractal dimensions and fractal curve and surface generation were presented with programming source codes. The isarithm algorithm described in the 1983 paper was modified and included in the book.

(2) Second, to overcome the issue of the lack of reliable software for computing fractals, Lam and collaborators with funding from NASA developed a software package called Image Characterization and Modeling System (ICAMS), which is available for the public upon request from the website (http://www.rsgis.envs.lsu.edu/icams.asp) at Louisiana State University. The software package contains major algorithms for computing the fractal dimensions of curves and surfaces at both global and local scales, with a special focus on remote sensing images. In addition, other key spatial and textural measures such as wavelets, lacunarity, and spatial autocorrelation were included in the software package (Lam *et al*. 1998, 2002; Quattrochi *et al*. 1997).

(3) Third, we extended the fractal measurement of elevation surfaces to other surfaces, namely remote sensing images (Lam 1990). This extension, together with the availability of ICAMS, has led to substantial research and application of fractals in remote sensing (Jaggi *et al*. 1993; Qiu *et al*. 1999; Emerson *et al*. 1999 and 2005; Quattrochi *et al.* 2001; Myint *et al*. 2004; Myint and Lam 2005; Zhou and Lam 2005; Ju and Lam 2009).

Through these studies, fractals have been found as an efficient index to evaluate human disturbance of landscapes (Read and Lam 2002), as a textural measure for more accurate image classification (Ju and Lam 2009), and as a tool for environmental monitoring and land use land cover change detection (Lam 2004 and 2008; Lam *et al*. 2009).

The impacts of our 1983 paper on non-academic sectors are harder to document. However, at a personal level, the experience in working with the 1983 article had a great impact on Shelberg's career. Upon returning from the Ohio State University to Defense Mapping Agency (DMA) in 1982, Shelberg became chief of a cartographic techniques office in 1985. This led to a variety of assignments to where he became the Program Manager for the Interoperable Map Software program in Washington, DC, a Department of Defense-wide software certification/reuse effort overseen by the then Defense Mapping Agency. Over the years, Shelberg led cartographic technical teams into the Czech and Slovak Republics to pave the way for international agreements with DMA. Shelberg supported and conducted a variety of studies and held numerous supervisory/technical positions. During 2007-2008 Shelberg was the in-country advisor/mentor to Afghanistan's civilian cartographic and geodetic head office (AGCHO in Kabul), and from 2010 to 2011, Shelberg was the in-country advisor/mentor to Iraq's Imagery and Mapping Directorate in Baghdad. Although Shelberg did not continue with his fractal research after his graduation with a MA degree in geography from the Ohio State University, the experience from conducting the fractal research has provided him the foundation for a successful career.

D. The challenges.

There is voluminous literature on fractals from many different groups in subsequent years following the publication of the 1983 paper. Many have found very good use of fractals in measuring or simulating a phenomenon, or testing hypotheses about a phenomenon. However, in the realm of fractal measurement of spatial phenomena, the challenge of resolving different results from different measurement methods remains. This is compounded by the inseparable concept between fractals and scale.

The beauty of the fractal model is its simplicity; adding more complexity to the original fractal model might add more reality but it could defeat the original purpose. This "fractal paradox", as coined in Lam (2009), remains to be addressed more effectively through more scientific research and real-world applications involving decision making. It appears that this research will be a continuing topic in Analytical Cartography as reviewed by Moellering (2000).

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The Photogrammetric Generation of Topographic Information: A Brief History

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ABSTRACT. Photogrammetry has always been a powerful tool for generating topographic information for automated mapping. The use of minicomputers for storing the measured data in the early 1980s prepared the way for a direct link between photogrammetry and GIS.

KEYWORDS. Topographic mapping, photogrammetry, GIS.

A. Title of AutoCarto Six paper.

Extended graphical plotting with the PLANICOMP.

B. Reason for paper.

The intent of the 1983 paper was to present photogrammetric solutions for digital storage of topographic map information, thus replacing graphical master manuscripts.

C. Mapping topography before 1983.

From the 18th century geometrically correct topographic maps were created by field survey methods. Very soon the plane table was the instrument for generating master maps in the field. It was not until the early 1920s that photogrammetry became the preferred method of mapping topography. For more than 50 years analogue stereoplotters with attached tracing tables were the workhorses for plotting map manuscripts all over the world.

Before the advent of usable and affordable microprocessors in the early 1970s the graphical representation of the topography was generated by simple pencil following. The photogrammetric operator had to trace any line feature and manually annotate any additional information to be derived from the stereomodel and to be shown in the master map.

The manufacturers first presented so-called digital tracing tables with microprocessor support around the mid-1970s. It then became possible to plot straight lines, automatically to complete polygons such as land parcel boundaries or rectangular buildings, and to mark points by symbols without moving the floating mark all the way round carefully. Later the automatic functions included curved lines (e. g. splines), various line styles such as dashed or point-dashed lines with selectable intervals, text along straight or curved lines, and plotting of points using digital coordinates.

D. State of the art 1983.

The increasing performance of microprocessors soon led to the development of then powerful microcomputers such as PDP 11 by Digital Equipment Corp. and HP 1000 of Hewlett Packard, supporting real time interaction and being programmable by the user. Since the mid-1970s this not only allowed the development of analytical stereoplotters with acceptable performance but also the storage of large volumes of data.

At first analytical plotters were directly connected to digital tracing tables to make the handling almost compatible with the analogue plotters. This made them more acceptable to operators while providing a smoother transition. However, the advantage of first storing the located and traced data, and plotting the information later was soon realised and implemented. As a result of the intermediate data check, correction and modification of the graphical information using a graphical monitor became possible.

By 1983 all major photogrammetric manufacturers had developed both hardware and software supporting this new procedure. Carl Zeiss, Oberkochen, for instance, had presented the following components:

- PLANICOMP analytical plotter with programs for on-line and off-line plotting;
- DZ 7 Tracing Table with on-line and off-line capabilities;
- GRAPH F1 routine library for off-line control of the DZ 7, various HP plotters and graphical terminals from any programs;
- DZ 7-AS Software Package for independent off-line use of DZ7;
- Plani-AS and its successor PLANIMAP for storing graphical data from analogue stereoplotters;
- On-line connection of INTERGRAPH workstation to Zeiss analogue plotters, e. g., PLANICART;
- Optical superimposition of INTERGRAPH screen into PLANICART eyepiece for immediate check of graphical data, and
- On-line connection of PLANICOMP to INTERGRAPH workstation.

E. Development since 1983.

Optical superimposition emerged as an efficient tool for the fast and correct photogrammetric digitizing of topographical data for maps. Zeiss soon presented its own solutions with VIDEOMAP in 1984 and as stereo-superimposition in 1988.

It took until 1987 for the GIS philosophy to enter photogrammetry. For its suite of photogrammetric instruments Zeiss introduced the PHOCUS software with an object-oriented, hierarchical data structure, enabling for example the easy change of graphical representation by using different code and symbol tables. In1989 Wild Leitz Heerbrugg presented System 9 in cooperation with Prime Computer Inc.

One may wonder why it took more than 20 years before photogrammetry met GIS. In 1966 Roger Tomlinson in Ottawa at the Department of Forestry and Rural Development had already developed the "Canada Geographic Information System" (CGIS), based on the then-available general purpose computers. The reason for the delay, in brief, is that for a new technology it generally takes almost four decades from the initial idea to its widespread use. This can be seen in cartography and photogrammetry, too (Figure 1).

Figure 1. History of development of GIS, analytical stereoplotters and digital photogrammetry.

	Phase	*Enactor*	*GIS*	*Analytical Stereoplotter*	*Digital Photogrammetry*
1	First idea / invention	scientist	1958 (Bickmore)	1957 (Helava)	1960s (digital image processing) 1981 (Sarjakowski: digital stereoplotter)
2	Basic research / first prototypes	engineer	1966 (Tomlinson)	mid 1960s (Bendix-OMI)	early 1980s
3	Refinement / Serial production	supplier	1970s (ESRI at al.)	1976 (Zeiss et al.)	around 1990
4	Market penetration	marketing & sales	1980s (market acceptance)	1980s	2000s
5	Market dominance	user	mid 1990s	1990s	2010s

So, be careful if somebody is talking about "state of the art". It may be a completely different technology, depending on whether the source is a user, a sales person, an engineer, a scientist, or even a utopian.

F. Today.

GIS, having replaced the former map making process, has converted photogrammetry from map drawing into feature extraction. The now wide-spread use of digital aerial photographs and even images from space paves the way for automatic feature extraction which is an ongoing field of research. Using digital photogrammetry, so-called "true orthophotos" have also become possible.

With Google Maps / Google Earth and Microsoft Virtual Earth (now Bing Maps 3D) the combination of GIS and aerial and space photography has become freely available for everybody.

G. Outlook.

The day may come when GIS and its Internet versions from Google and Microsoft will be available as near real-time Geographic Information Systems.

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The Map Overlay and Statistical System (MOSS) – A Historical Perspective

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ABSTRACT. Our industry is littered with hundreds of geospatial (GIS) technologies that have been lost to history – and only in the last 40 years! In 1977, as part of a U.S. Fish and Wildlife Service project, I compiled a list of 85 software systems that supported some level of geospatial data processing and analytics. Of this list, only a few are ever referenced in current GIS histories and/or timelines. In 1983, I wrote a contribution for AutoCarto 6 titled, "MOSS – A State of the Union Address". Since then, information and the historical importance of MOSS have, for the most part, been lost to the GIS collective conscience. This retrospective provides details related to the development of MOSS and the impacts – technical and otherwise – that MOSS had on the early growth of our industry.

KEYWORDS. GIS, MOSS, history, USFWS, open source.

A. Title of AutoCarto Six paper.

MOSS – A state of the union address.

B. Introduction.

Several years ago, I browsed a number of GIS books and GIS historical retrospectives. For reasons of personal interest, I checked out what the authors had to say about MOSS, the Map Overlay and Statistical System.

While MOSS was often mentioned, that was not always the case, and often there was a lack of both historical accuracy and content.

A classic example of omission is by Coppock and Rind (1991) in their book, the *History of GIS*. MOSS is not even mentioned – not even in a footnote!

And, an interesting misconception for the period in the 1970s is voiced by Tomlinson (1988):

> "…the 1970s as a period of lateral diffusion rather than of innovation . . ."

While the first part of the statement is true, the second part regarding innovation is not. As a case in point, the work of the U.S. Fish and Wildlife Service and the development of MOSS were truly innovative, as will be described below.

Since I "lived" the MOSS story, I felt that it would be interesting to re-read a number of documents from the 1970s and write a short but definitive history of the early days of MOSS. One item I quickly discovered in my research is that MOSS as a software product is still alive and well, and available as Open Source! Not bad for a GIS software product that was first developed in 1978.

The development and use of MOSS was a very important milestone in the evolution of GIS. MOSS was the first broadly deployed, vector based, interactive GIS. Second, MOSS was the first GIS to be deployed for production use on mini-computers, and then later UNIX workstations. Third, MOSS was the first GIS to provide integrated vector and raster processing. Finally, and perhaps most importantly, dozens of state and federal agencies' staff were able to cost effectively use and learn about GIS at a time when there had been very little exposure as to the power and usefulness of GIS.

In a sense, MOSS provided the educational springboard that allowed many of these agencies to use the lessons learned in implementing and using MOSS to grow and expand their GIS "reach", purchasing and using more powerful, commercially supported systems. Further, MOSS was the world's first open source GIS project predating GRASS by several years – although back then there was no formal definition of what we now mean by open source!

C. Background – Why was MOSS developed?

In the middle 1970s, coal-mining activities in the Rocky Mountain states began to accelerate. In response, the U.S. Fish and Wildlife Service was tasked with evaluating the impacts of strip mine development on wildlife and wildlife habitat. The Service was further tasked with evaluating and making recommendations regarding habitat mitigation. Professionals within the USFWS felt that the (at that time) nascent potential of GIS as an analysis and modeling tool was exactly what was required to aid the wildlife biologists map habitat and develop habitat mitigation scenarios.

With funding from the EPA Coal Program, in early 1976 the USFWS issued a Request for Proposals (RFP). As documented in the RFP, the scope of the project included doing a user needs assessment, developing a GIS functional scope, evaluating existing GIS technologies, and making recommendations to the USFWS as to the appropriate course of action for the development and deployment of GIS technology.

In late 1976, the contract[1] was awarded to the Federation of Rocky Mountain States, a not-for-profit organization that eventually evolved into the Western Governors' Policy Office. The USFWS group given responsibility to oversee the contract and participate in the user needs assessment and demonstrations was the Western Energy and Land Use

[1] Contract number 14-16-0008-2155.

Team (WELUT). The project leader for the FRMS was Larry Salmon and the contracting technical representative (COTR) for the Government was Ken Burnham. The complete FRMS GIS team came together in January of 1977 and consisted of myself, George Nez, Jim Gropper, and John Hammill. I was hired as the GIS architect and programmer.

D. Work begins.

For the first six months of 1977, the team worked on two tasks: “A User Needs Assessment” and an “Inventory of Existing GIS Technology”. The needs assessment involved interviewing wildlife biologists, natural resources planners, and other professionals who would be involved in wildlife habitat definition and habitat mitigation.

The objective of the interview was twofold: 1) To elicit the types of GIS functions and GIS environment that they would need in order to fulfill the mandated mission of the mitigation studies; and, 2) To begin educating USFWS staff on the potential uses and benefits of GIS. FRMS staff and WELUT staff traveled to numerous USFWS field offices and interviewed dozens of individuals. The results of the assessment were published in the spring of 1977 (WELUT 1977a).

Concurrently, I was doing an inventory of existing public domain and commercial GIS technology. Using previous work done by the International Geographical Union (Tomlinson *et. al*. 1976), personal contacts, and research, approximately 85 different mapping and GIS software packages were identified. Of these, 54 had enough documentation and basic, required functionality to warrant further analysis. A basic set of information was collected on each system (hardware, operating system, basic GIS functions supported, etc.).

In a sense, the survey and inventory was similar to those now published in various GIS magazines and industry analysts’ reports. The main difference is that we collected the information as opposed to sending out a survey and asking companies and individuals to complete the survey.

The USFWS published the results of the inventory the summer of 1977 (WELUT 1977b). This document provides a table listing the 85 applications and systems. For the 54 applications and systems with adequate documentation, this document also provides information on product name, programming language, required operating system, GIS capabilities, data model(s) used (vector vs. raster), level of documentation, and whether support was available – or not. In the summary of the document, eleven complete systems and components of fourteen systems were identified for additional study. This 1977 document is a valuable historical document, as it has information and details of systems long extinct and forgotten.[2]

The results of the user needs assessment coupled with new industry and technology knowledge allowed us to develop a GIS functional needs document that specifically

[2] I will be scanning and uploading this document to my Reed’s History of GIS project: https://sites.google.com/site/reedsgishistory/

focused on the GIS requirements for the USFWS and the habitat mitigation process (WELUT 1977c). We then were able to compare the functional specification against the inventory of existing systems.

It quickly became apparent that none of the existing systems could meet even half of the requirements of the USFWS. Further, all the inventoried systems operated in batch mode. There was a general feeling among the USFWS/WELUT staff that an interactive GIS would be much more useful as part of a decision making process. Since I had used both batch and interactive GIS applications in graduate school, I strongly supported the interactive approach. As a result, we had to make a “build or buy” decision.

A very critical and interesting discussion took place at this point. Some FRMS staff and some at WELUT were sold on the idea of using a batch mapping system called CMS (Computer Mapping System). Functionally, it was similar to Symap. Its primary output mode was the line printer. As far as I know, CMS is the only “GIS” ever written in COBOL!

After weeks of argument, the decision was made not to use CMS. Also, since none of the commercially available systems at the time had the required functionality or they were way too expensive, the decision was to design and implement a new GIS based on the requirements uncovered by the needs assessment and documented in the functional specification. The stipulation by the decision committee was to use as much of the public domain code documented in the inventory as was feasible in the new system.

E. Software development.

With this background of well-documented requirements and systems information, the design of MOSS began during the summer of 1977. Once the group agreed on the design, I began programming MOSS. Eventually, a set of shared libraries of common functions, such as a graphics library, a math library, and a text processing library were developed. These shared libraries with documented interfaces allowed for the very rapid development of the complete software system. Many of these base level subroutines were extensions of work done by myself and other geography graduate students in the GIS laboratory at SUNY Buffalo. The development environment was a CDC mainframe running the KRONOS operating system. Fortran IV was the development language. Graphics presentation and code development was done on a Tektronix 4010.

Since the decision was to implement an interactive system, we needed a user interaction language. Using the results of the user needs assessment, we were then able to define an English-like language for user interaction for the new GIS. We also decided to enforce entry of basic map metadata (including coordinate reference system metadata!) and provide the ability for the user to browse the metadata and select map data based on the metadata.

We decided to use simple action verbs (PLOT to plot a map, SHADE to generate a choropleth map, etc.) with simple subjects and modifiers (PLOT ROADS) to plot a roads map. We also raised the issue of how once users selected a map set, they could continue processing on the result of the select without having to constantly re-select the map or set of maps. We came up with the concept of "Active IDs".

These IDs are equivalent to views or query sets. For example, if the user selected interstates from a road map, the result of this select was "remembered" by the system and given a unique identifier. The user could then reference this selected map set by its ID number. So, for example, the user could then enter PLOT 3 to plot map set ID 3 or could enter OVERLAY (2 4) to perform polygon overlay on selected map sets 2 and 4.

This approach made it much easier for users to develop and use sequences of commands to perform a given work flow or modeling operation. We further extended this concept so that users could save session state information, such as metadata about current selected data sets, and reuse this information from working session to working session.

Using the defined user language, the functional specification, and the systems design for guidance, in late 1977 I began implementing high-level user action functions in the software. These higher-level functions accessed the shared libraries already previously built and tested. Extensive use of existing public domain code helped accelerate the development process. For example, code for point-in-polygon was extracted from software done by David Douglas, a polygon cross-hatching and fill capability was "borrowed" from code by Waldo Tobler, and the vector-to-raster conversion software was a recoding into Fortran of the COBOL code in the CMS system.

As a point of interest, the commitment to using existing public domain code continued through the full development and deployment lifecycle for MOSS. Further, all MOSS software was maintained in a source control system, and was available to any developer to review and add to. This became the foundation for MOSS evolving into an endorsed open source project.

This approach allowed for the rapid development and use of MOSS in a pilot project in 1978. The pilot project was done for several reasons:

- Provide a validation of the capabilities and implementation approach for the MOSS GIS;
- Help educate FWS staff on the use and power of a GIS;
- Provide iterative feedback to be used to evolve and enhance MOSS;
- Prove to the funding organizations that they were getting their money's worth.

By 1979, version 10 of MOSS had been implemented on the CDC mainframe. This was the final version developed as part of the FRMS contract. At this time, I became an employee of the USFWS WELUT organization. Denny Parker, the founder of what is now GeoWorld, was my boss. My first task as a federal employee was to port the CDC version of MOSS to a Data General C330 minicomputer running the AOS operating system.

Another part of this project was to integrate MOSS with another software package that had been developed under contract by Autometric for the National Wetlands Inventory. The Wetlands Analytical Mapping System (WAMS) was an advanced map digitizing and edit package for topologically structured vector data. All work on these projects was completed in early 1980. As far as I know, WAMS was the first interactive digitizing system for capturing and structuring map data as topology in real time. But WAMS is another story, worthy of its own chapter in the history of GIS.

By the middle of 1980, the WAMS/MOSS software suite was ready for production use, not only within the Fish and Wildlife Service but also in other Federal agencies. The Oregon state office of the Bureau of Land Management (BLM) was the first non-FWS group to install and use MOSS and WAMS.

Within a couple of years, MOSS was being used in the Bureau of Indian Affairs, multiple BLM state offices, the Bureau of Reclamation, National Park Service, U.S. Army Engineering Topographic Labs, Fish and Wildlife Service, and numerous state, local and university organizations.

F. Technical innovations.

As Tomlinson suggests, perhaps in general there was not much GIS technical innovation in the development of GIS software during the 1970s. This belief, however, was definitely not true for the development and deployment of MOSS and WAMS. MOSS had a number of technical innovations completed in the late 1970s, including:

- Enforced entry, maintenance, and use of metadata;
- English-like command line entry with integrated prompting and help as required;
- Integrated support of vector and raster formats;
- First completely interactive, full function vector GIS (COMARC COMPIS was interactive for most functions but not to the same level as MOSS);
- Maintenance and conversion of coordinate reference systems (including transformations);
- Spatial views to enable easy workflows;
- Consistent compression of coordinates to insure quality and accuracy;
- Tiled database structure for both vector and raster data;
- Key commands such as PLOT or SHADE worked on both vector and raster data;
- First public domain GIS to run on a minicomputer;
- Open Source philosophy.

Such innovations led to numerous very innovative MOSS related activities in the early to mid-1980s.

G. Legacy.

For the next several years, MOSS was extensively and successfully used by these agencies to complete numerous projects. In the process, hundreds of federal, state, and local employees gained hands-on experience using GIS technology as part of their jobs. The USFWS staff and contractors developed complete systems documentation, detailed user's manuals and guides, reference manuals, and tutorials. In the early 1980s, a series of annual MOSS users' conferences started. Perhaps the widespread use of MOSS helped break down the barriers to the use of GIS technology, helping to pave the way for the adoption and use of geospatial technology today.

But the MOSS legacy does not stop here. In the early 1980s, Autometric under contract to the BML and USFWS, provided on-going support and maintenance of AMS and MOSS. They also provided technology transfer services to install the software into both federal and local government sites, provide training, and ongoing support. Autometric staff also ported the software to other operating system environments, such as VMS and UNIX. This work allowed Autometric to build an extremely experienced staff of GIS programmers and support professionals.

In 1984, a small group of engineers decided the time was right to design and implement an entirely new GIS software package. A six month intensive design period ensued. The design took into consideration all the strengths – and weaknesses – of both AMS and MOSS. The team considered lessons learned in porting AMS and MOSS to UNIX. They also took advantage of the results of several projects that focused on the data structures and algorithms needed for real time collection and maintenance of topologically structured spatial data.

By April 1985, version 0 of DeltaMap was publicly announced. Since design and implementation of DeltaMap reflected the strengths of AMS and MOSS, such features as the English-oriented command language, metadata, session state information, and spatial views were maintained.

However, contrary to some industry beliefs, DeltaMap represented almost 100% new code. Because DeltaMap used a topologically structured data model as opposed to the full polygon data model of MOSS, very little MOSS code could be used to develop DeltaMap. DeltaMap – later GenaMap – was first installed at a customer site in 1986. GenaMap lives on, and is now an integral component of a broad set of applications for the telecommunications industry being deployed in Europe and South America.

H. Summary.

From its somewhat humble beginnings in the U.S, Fish and Wildlife Service, MOSS flourished for many years and enabled dozens of agencies and federal offices to compile a comprehensive digital map database and complete numerous projects. Much of these data have since been converted into other GIS formats. All of the agencies that began their GIS experience with MOSS have moved to using a variety of commercial products. But the MOSS legacy lives on, in having paved the way for these organizations being able to make better and more effective use of GIS technology to meet today's policy and mandate challenges.

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Automated Cartographic-Quality Map Feature Labeling

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ABSTRACT. One of the most challenging tasks of map production is the placement of the point-, line- and area-feature names of a map according to established cartographic rules, a task that over the centuries could be performed only by highly trained cartographers. Starting in the late 1970s, work was started to automate this process. The results of pioneering work were described in an AutoCarto paper in 1983. Enormous progress has been made since that time, and the purpose of this retrospective paper is to describe the accomplishments that have been made and the current state of the map-feature labeling task.

KEYWORDS. Automated text placement, name positioning, cartography.

A. Title of AutoCarto Six Paper.

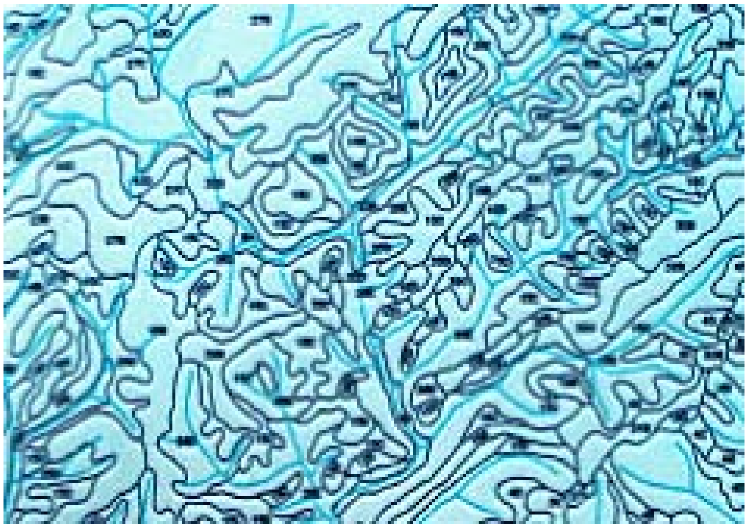
A program for automatic name placement.

B. Reason for paper.

The objective of the 1983 paper was to show that it was possible to automate the labeling of the point-, line-, and area-feature names in a geographic map. The paper presented in 1983 described the introduction of software for the *automatic* labeling of the point, line and area features of a map in accordance with established cartographic conventions. In many ways the paper was revolutionary because prior to that time there had been no satisfactory software available for automatically labeling map features, and it was widely believed in the mapping industry that automatic placement of map features' names in accordance with cartographic conventions was a task that was simply beyond the capabilities of computers. In the 30 years since then enormous progress has been made and today virtually all map production includes automatic feature labeling. This paper describes some of the progress made since the publication of the original paper.

The original paper, which was based on the doctoral dissertation of John Ahn under the guidance of Professor Freeman, got a lot of attention worldwide. A number of other theses and publications followed in subsequent years and around 1992 Professor Freeman was approached by the US Department of Agriculture's Soil Conservation Service as to whether automatic feature labeling could be applied to the so-called soil maps they produce. It was believed possible and a development effort was undertaken, resulting in the delivery of software that made it possible for the Agency to label soil maps automatically in a matter of minutes instead of the many days it took when the task was done manually by a skilled cartographer. An example of the section of an automatically labeled soil map is shown in Fig. 1. The different numbers refer to the soil properties of the delineated areas, with the specific characteristics identifiable by referring the indicated number to a soil properties table.

Figure 1. Computer-labelled soil map.



C. Subsequent developments.

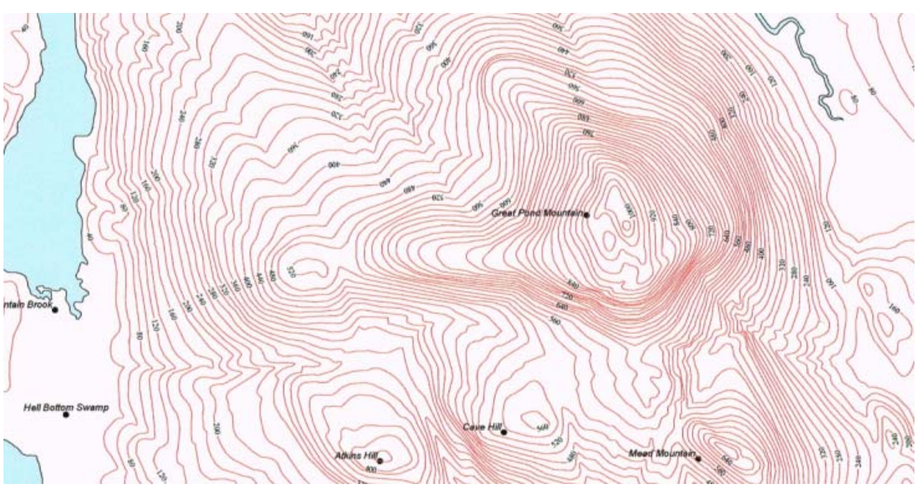
The automatic soil-map label placement was the first significant commercial success and it attracted wide attention. Largely as a result of this the US Census Bureau contacted Freeman around 1996 about the use of automatic label placement software for the millions of local maps required for carrying out the year-2000 decennial census of the United States. The scope (and national responsibilities) of this task required that the work be moved from a university research laboratory to a commercial company.

In 1997 MapText, Inc. was formed, with Professor Freeman as its president. The company devoted its development efforts to automatic name placement for the maps required for the Census 2000. The required software was developed and successfully used by the US Census Bureau in the production of some 20 million local-area maps. Numerous new publications and conference presentations describing the results of this effort occurred over the years.

Once MapText, Inc. had been created, it also sought out other customers for its software. It found these mainly among government agencies all over the world – as far away as New Zealand. Work on improving the automatic map labeling software continued at a steady pace, with refinement in the precise positioning of names, speedup of the placement process, and extension of the placement capabilities to more specialized label placement needs. This resulted in numerous publications, patents, and conference paper presentations. Automatic label placement was extended to the production of nautical charts, airline charts, and some years later also to the automatic labeling of the elevation contours of contour maps. Aeronautical charts must clearly show the information a pilot will need in guiding an airplane, and in the case of elevation contours the requirement is that adjacent contours be labeled so that the top of an elevation label always face the next higher elevation. Examples of these, automatically labeled without any human intervention, are shown in Figures 2 and 3, respectively.

Figure 2. Portion of an aeronautical chart with its features precisely labeled by computer software.

Figure 3. Elevation contour map automatically labeled according to standard cartographic requirements.



Automatic label placement for airline charts was particularly significant because of the large market for these charts and the required precision. As a result of the success with airline charts, a major international airline (Lufthansa Systems) made an offer to purchase the company. The offer was accepted and the purchase consummated in late 2005. MapText, Inc. now operates as a division of Lufthansa; however, the scope of its activities continues to span the complete range of cartographic text placement applications.

D. Conclusions.

Automated placement of a map's point-, line-, and area-feature names according to accepted cartographic requirements was deemed virtually impossible prior to the appearance of the 1983 AutoCarto paper. In the years since that time, enormous strides have been made to achieve high-quality text placement for the widest possible range of map types – from soil-survey maps to city maps, country maps, nautical charts and even aeronautical charts.

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Technology, Information, Communications, and Instant Maps

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ABSTRACT. This paper recalls the processes involved in the making of a colour atlas. The project failed. The reasons for undertaking it are as valid today as in the mid-1980s. It was conceived with a vision for on-going, rapid updating on a biennial timeframe. Changes in print technology, global communications, and the adoption of instant messaging by emerging generations suggests that the target audiences for the original mapping concept might well become involved in the constant revision and open access processes that provide instant maps.

KEYWORDS. Mapping social and economic data, access to information, automated cartographic maps, paradigm shift, technological change, instant answers, dynamic maps, instant feedback.

A. Title of AutoCarto Six paper.

The making of the Far Eastern Economic Review Economic and Social Atlas of the Pacific Basin.

B. Reason for paper?

In 1982-83 we were encouraged by the rise of computer-assisted cartography as a means for the rapid updating of maps that could convey the essence of social and economic change in our region, comprising South Asia, the western Pacific Rim and Pacific Island realm (Forbes, *et al* 1983). Our research brief at The Australian National University's Research School of Pacific Studies was to focus beyond Australia to the countries in this fast developing region to the north with its very significant contrasts in terms of demographic indices, territorial extent, resource distribution, economic development, and political governance regimes.

Conventional atlases did not meet the need for visual representations of current social and economic parameters that might inform fellow researchers and decision makers with interests in this region. Our goal, therefore, was to produce a computer-based colour atlas of the Asia and Pacific Region. Given its growing global importance and complexity, the region was ripe for our project.

This focus required the selection of a suitable map projection for the region that would minimise the spatial distortions that might otherwise mislead comparative evaluation of mapped data. The map base created for this purpose was the azimuthal equidistant projection centred on 120^0 E, 6^0 N.

There was seen to be a need for immediacy in access to information. There was value also seen in detailing change as it took place. We had an interested client, the Far Eastern Economic Review, as they saw possibilities of producing a biennial companion volume to their Asia Yearbook. The atlas' visual data could complement their in-depth analyses of regional issues.

We felt, as geographers, that we could provide more than the just the assembly of factual information. We could also seek to balance the breadth of topics covered, and add our own explanatory text for each map to help make them comprehensible for a wide audience.

C. Thoughts that shaped the atlas project design and execution.

Our aim was for an atlas that would be broad brush in its scope, would focus on immediate issues (many of them of a fast-changing socio-economic nature), and displayed in a way that would heighten reader interest, each map complemented by a 600-word explanatory text.

A number of our academic contemporaries considered our approach to be "too commercial" or "not academic enough", but we contended then and have been vindicated subsequently, that automated cartographic maps actually provide more information relevant to academics, at the same time informing a much wider public about changing economic and social matters.

Our project was part of experimental work on a system called *Colourview* being investigated by the Canberra based Commonwealth Scientific and Industrial Organisation (CSIRO) in conjunction with a proprietary firm TECHWAY based in Sydney, Australia.

In essence we had to define closed polygons that could be in-filled with selected colours, and then have overlays of symbols to both expand the information content as well as make the maps more appealing. One polygon did not necessarily include all the territory of a single country, as some countries comprised many separated islands. These multiple polygons had to be treated as a set. Our co-author, Simon Wild, used Tecknicad to send data via a mainframe computer to a TA10 plotter which produced either scribed or cut-out polygon separations in negative form ready for plate-making for four-colour process printing.

Our atlas endeavour necessitated "the building up of a series of coherent, consistent and, as near as possible, comprehensive data bases, most frequently derived from a variety of sources."

Significant sources of global information included organisations such as the United Nations, the International Labour Office, and the World Bank. Other sources dealt with particular sets of countries of interest to the project. These sources included The Economic and Social Commission for Asia and the Pacific (ESCAP), the Far Eastern Economic Review, the South Pacific Commission, the Central Intelligence Agency's National Foreign Assessment Centre Handbooks, and special sources such as Amnesty International's reports on political prisoners and Boulding's (1976) Handbook of International Data on Women.

This compilation proved to be a far from easy task. Data gaps or improbable estimates were encountered. We had hopes that in printing incomplete maps it would spur various authorities to provide the missing or more accurate data in follow-up editions so that their territories would be included. However, for some territories, a blank space might well have seemed preferable to having their socio-economic data mapped because their territory might not compare favourably with others. Further, there are often considerable time lags before data are published, which is not helpful for an atlas that aims to be as contemporary as possible.

The contents of the first edition of the proposed atlas intended to have four world maps that put the Asian and Pacific economies in a world context. Thirteen maps followed, highlighting what we saw as significant aspects of economy and finance within the region. A further four maps illustrated the structure of industrial production, five on energy and mineral resources, and seven on agricultural production. The remainder of the atlas design included three maps on the workforce, ten on population issues, four on human settlements and the environment, two on defence matters, and seven on transport and communication.

We were not threatened by any rival atlas competition. We were challenged by production difficulties. We saw data-gathering as a process that would improve over time from edition to edition. We were thwarted in our ambition, but there are positive lessons that can be considered.

D. Hurdles.

The use of geographic information systems (GIS) was an emerging technology that offered an inbuilt mapping capability still needing refinement. Since that era there has been a paradigm shift in the way mapped information can be accessed worldwide using the Internet, with individuals able to download and print their own copies of specific maps on personal desktop colour printers or even onto their smart phones.

Many of the technical difficulties we faced with multiple photographic processing of conventional cartographic line-work at different scales have now been eliminated. Further, there is no need to produce colour separations for conventional printing presses, as electronic scanners do that automatically and the designer map-maker does not need to ever relinquish control from start to finish.

Issues encountered that led to the cancellation of the publishing contract were related to: control of photographic quality, wherein images conveyed between different parties became compromised by the insertion of unintentional blemishes that then showed up as data; computer graphics technology then available was in its infancy for the type of end product we aimed to produce; conventional printing requirements for exact registrations for separate colour plate overlays onto the primary base maps did not happen because of compounding photographic distortions; incompleteness and reliability of statistical data sources; and, the high pressure of meeting commercial deadlines.

Our sales pitch had been rapid compilation and production. We had set ourselves six months to iron out problems, and did achieve what we thought was print-ready material in two months, but quality control in the passage of product through different technologies proved to be a dream still over the horizon.

Automated computer cartography was fast developing at the time, and our vision seemed achievable. However, it appears that we were probably expecting too much too soon. Later advances in computer-based graphics and in communications technology have enabled automated map production to become a viable reality. A by-product we foresaw arising from computer-generated maps using regularly updated databases was the ability to conduct longitudinal analysis and examination of trends. We were frustrated in our endeavour, but that vision is now achievable.

E. Prospect.

Major social and cultural issues are headline matters in the global media. One only has to mention people smuggling, drug running, refugees (both political and environmental), religious discrimination, dictatorships, piracy, droughts, famines, fires, earthquakes, floods and tsunami. Political turmoil persists and engulfs places that once epitomised the word “pacific”.

The title to this paper mentions three things – technology, information and communications – in the context of instant maps. In the next several paragraphs I briefly comment on several prospects that come to mind.

We have witnessed in the past 30 years technological advances in hardware and computer software that are simply amazing, and the pace of development continues unabated and is accelerating. This technological advance impacts the way we print material and distribute or access it. Publishers are facing and need to adjust to the rise of e-books (such as *AutoCarto Six Retrospective*) supplanting conventional printed books and magazines.

Most authors of articles produce the manuscripts themselves, eliminating the traditional typist, and sometimes also escaping an editor as is evident in typo-riddled pieces that appear in daily newspapers. They can publish independently using the Internet as a means of alerting potential readers, and they can leave it to the recipients to choose whether they will be satisfied with an electronic version to read on their very physically transportable book-sized devices, or whether they want a printed hard copy. They can store the material in cloud computer mode, such that bookshelves full of dusty tomes may decline in linear extent, perhaps leaving wall space for the display of frequently changed artwork (or maps), also available on-line.

Information is more accessible – both reliable and unreliable. That information is subjected to the more widespread scrutiny of global peer review and challenge. We mostly welcome this potential to advance the prospect that ideas and concepts and facts can be weighed by people of many cultures, ideologies, and levels of education.

Without communications advances we would still remain pockets of isolation, smug in our considerable ignorance. We would largely miss the demonstration effect of seeing global incidents as they occur. For some that might seem an idyllic situation. Not so for the emergent generations, whose fingers and thumbs seem to be in constant use exchanging messages and extracting instant answers to just about any question using their mobile communications devices. The type of information can include how to navigate from A to B avoiding C or D, or seeing visuals of how places once were, overlaid by the present built and transformed environment. Heritage can be recalled with an App on a smart phone or tablet. Security monitoring may leave no place to hide a thought.

We throw out the challenge to more youthful researchers who embrace the use of social media, such that instead of maps as snapshots based on dated statistics, dynamic maps might be produced for any issue in any region inviting constant feedback and continuous validation and improvement. Our atlas project stood on the threshold of this revolution without knowing it. We wanted to supply social and economic information in a mapped form. The target audiences for such a publication can now provide an instant feedback.

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Note: The co-authors for the original research paper were from the Department of Human Geography, Research School of Pacific Studies, Australian National University, Australia.

Acknowledgement

I wish to acknowledge the assistance of two of my fellow authors mentioned in the note above. Professor Emeritus, Michael Taylor, encouraged me to think about the contemporary social and economic indicators we might consider. Keith Mitchell, cartographer legend at Australian National University, provided some technical details on the production process for our atlas project.

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Early Electronic Atlases - Synergy Between Classical and Modern Cartography and GeoVisualization

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ABSTRACT. Classical geographic and cartographic concepts and geospatial information visualization and processing are continuously enhanced by rapidly advancing technologies and evolving methodologies. The field of geospatial processing made tremendous progress from the time that the AutoCarto six papers were published. Many concepts discussed in the 1983 paper have become a reality. This retrospective paper summarizes salient points discussed in 1983 and reflects on the key ideas presented in that paper. These are: the definition of an electronic atlas; efficient processing in the raster mode on small computers; synergy between the remote sensing mode of data handling in raster mode and cartographic data processing in vector mode; the design of cartographic databases; linkages between cartographic mapping systems and GIS; authoritative cartographic products and user-generated information; rule-based generalization; qualitative and quantitative analysis of geographic information and creative geovisualizations; as well as the need for theoretical bases in computer-assisted or Internet-based cyber cartography. Finally, it discusses the impact the electronic atlas concept had in the international cartographic community and in Canada.

KEYWORDS. Electronic atlases, cartographic mapping systems, geovisualizations, rule-based generalization, authoritative maps, user-generated information.

A. Title of the AutoCarto Six paper.

Towards an electronic atlas.

B. Reason for the paper.

There were three main reasons why the 1983 paper was written.

1. To share selected ideas developed during study conducted (1977-1980) at the Departments of Cartography and Computer Science of the Swiss Federal Institute of Technology (ETH – Zurich). This study focused on advantages of raster (primarily used in the remote sensing field) and vector (used predominantly in the automated mapping field) modes of data processing (Siekierska 1980).

2. To draw attention to the usefulness of a cartographic "Visual Thresholds Generalization" theory developed by Polish cartographer, Prof. Lech Ratajski (Ratajski 1973). This theory provides a valuable basis for computer-assisted mapping and geovisualization, including automatic symbol translation depending on the scale of the map displayed. This theory provides bases for scaleless visualization based on automated generalization and enlargement.

3. To discuss the concept of an electronic atlas, implemented in the Graphic Work Station (GWS) system (Siekierska 1983), which was intended to achieve geovisualization by linking a classical cartographic product (the atlas) and geographic and cartographic information and mapping systems.

C. Thoughts shaping the design of the 1983 paper.

C1. Synergy between the classical cartographic concept (atlas) and new opportunities to derive and communicate geographic information (GIS) in digital form.

Classical cartographic and geographic concepts were given new dimensions when implemented in computer-based systems which provided a gamut of new opportunities for communicating and visualizing geographic knowledge in a creative and innovative way.

The GWS system developed within the National Atlas of Canada program aimed to preserve classical cartographic concepts such as "a map" or "an atlas", but at the same time to demonstrate new ways of presenting cartographic information as well as to provide opportunities to analyze data and derive new information.

The primary purpose of an electronic atlas was to provide the capability to display a systematic, authoritative collection of maps created by expert geographers. Secondly, it was to provide the opportunity to analyze databases associated with the maps to generate new information and to enable the creation of maps by the users themselves.

C2. Advantages of synergy between the raster and vector modes of processing.

Creative innovations frequently happen at the convergence of several fields.

In the development of an electronic atlas, the concept of handling data in both raster and vector modes of processing was emphasized. The fields involved were remote sensing, automated mapping, and computer science or information technology. The synergy was achieved by a combination of hardware and software used in the remote sensing and automated mapping systems. The processing of data in the GWS was in both raster and vector mode depending on the nature of data, intended functionality, and ease of processing.

C3. Need for multipurpose systems to accommodate the needs of "map readers" and "geospatial data analysers".

The electronic atlas system was intended for people who would "read" in a modern interactive environment previously published electronic maps, as well as for the "tech-savvy" GIS expert users who would access underlying databases and analyze associated information and/or create their own maps. The concept was to have an analytical as well as read-only mapping system which could satisfy the needs of a wide range of users.

C4. Value of scientific exchange and bridging cartography, GIS, and computer science.

The more general thought was to emphasize the value of sharing the science developed at various research centres in various fields, including: the "Visual Threshold Generalization" theory for which the Department of Cartography of Warsaw University became known; the computer language Pascal developed in the Computer Science Department of the ETH – Zurich, and the high cartographic standards of the ETH Department of Cartography, (even in the 80s, Swiss maps were produced using glass plates to ensure the precision of reproduction); and, and the research carried out within the Canadian government, which introduced the widely used term Geographic Information Systems (GIS) coined at Environment Canada by Roger Tomlinson.

D. Structure of the paper.

The main sections of the 1983 paper were: hardware and software configuration; database design; cartographic and geographic functions; and conclusions, which included recommendations for the future (Siekierska 1983). Each section is briefly outlined as context for my retrospective comments about the electronic atlas project and system.

D1. Hardware and software configuration.

The selection of hardware was influenced by the latest technology used in remote sensing and automated mapping systems.

In the early 80s the hardware was severely limited in the speed of processing and range of functionality that computer-based systems could provide. The GWS or electronic atlas prototype system Mark1 was implemented on the PDP, LSI 11/23 computer with only 256 KB internal memory, supported by the high-speed disk storage of 60 MB capacity. The essential part of the configuration was a Lexidata 3400 medium resolution display system, with a separate programmable high-speed memory with 9 memory slots capable of displaying simultaneously 16 separate map overlays. Further, the monitor had a joy stick for controlling interactive functions and a tablet with user-friendly simplified menus. This configuration was a hybrid setup used in remote sensing and in automated mapping.

The programming language used was primarily Pascal, developed in the 1970s at ETH-Zurich. It provided advantages over Fortran, commonly used in North America. For example, it was possible to define matrices, as a data type, which permitted effective processing of raster data. For efficiency of processing on small computers some modules were programmed in the machine language, Assembly.

There is no comparison with the efficiency of computer processing in the last 30 years, it grew exponentially.

D2. Database design.

The database of the Graphic Work Station was designed specifically to handle large amounts of geospatial data. It incorporated positional vector data, thematic attribute data, and cartographic representation files. By combining these three types of files, the user was able to create raster output files, either permanent or temporary.

Because raster files result in very large data sets, to facilitate processing and interactive analysis the files were subdivided into smaller units called “mapels”.

Another unique characteristic of the GWS system was use of video look-up tables and memory planes, which were linked to the attribute data and provided the higher intelligence of interactive raster data processing.

The database configuration and in-house developed database management system reflected the type of data used, the scope of geographical analysis to be performed, as well as cartographic visualization including animations and simulation of future situations and distributions such as, for example, the depletion of oil fields in Alberta.

The database files reflected the nature of geographic phenomena, e.g., static or dynamic, and discrete or continuous distributions. The cartographic specification tables provided the capability to select types of representation most suitable for the nature of specific geographic elements, including rules for automated symbol conversion during the generalization and enlargement progresses.

Another important concept was the use of permanent output files for the authoritative set of maps, and temporary output files for storing the results of analysis performed by users. Therefore, the concepts of an atlas and a GIS were preserved. The database and system design was intended to facilitate a wide range of cartographic and geographic analysis functions, as well as to ensure the publication of the authoritative national atlas electronic maps.

At the present time, all geospatial data processing organizations and institutions use commercial database management systems. However, the concept of authoritative and user-generated information is still on the agenda.

D3. Cartographic functions.

The cartographic functions implemented in the GWS were for creation of maps by the map authors, and for display of user-generated information. These included: assigning type of symbols to various map features; structuring map overlays to define visual priorities; the interactive, semi-automated selection of colour scales; and the use of special effects such as blink or animation. The animation functions most suitable for displaying dynamic, time-dependent, geographic phenomena were not possible in conventional cartography.

The most advanced cartographic function implemented in the system was that of rule-based generalization. This function was based on the Visual Thresholds Generalization theory of Professor Lech Ratajski (Ratajski 1973). This theory advocates the conversion of symbol types when the visibility threshold has been reached. The conversion threshold and the type of symbols were defined in the cartographic definition tables.

The maps in the GWS were created by geographers and cartographers working within the National Atlas of Canada program, and represented an official, authoritative set of electronic atlas maps. However, the system also provided interactive design capabilities for those who wished to create their own maps, or to modify existing maps for a particular purpose.

The existence of the authoritative set of maps was an important distinguishing element which differentiated electronic atlases from the GIS-type systems (Siekierska 1990a).

D4. Geographic analysis functions.

The analytical functions of the Graphic Work Station system resembled those commonly available in a GIS. However, the electronic mapping system had a quite different emphasis than the GIS, where the focus is on information retrieval and analysis. That is, in the electronic mapping system emphasis is on presentation and display of spatial information, *i.e*., communication in the form of maps (Siekierska 1983).

The analytical functions in the GWS included database queries, selection of class intervals based on basic statistics such as means, standard deviations and frequency distribution histograms, and so on. The system also included a visual aid for users to analyze the frequency distribution curve.

The interactive manipulation class levels in the histograms were synchronized with the spatial distribution on the map itself. This function provided mathematical and geographical spatial analysis at the same time. The same principle applied also to numerical and graphical derivation of intersections and unions between various distributions of information stored in separate overlays.

Another function included in the GWS, which is now commonly used in Google-map type systems, was the calculation of distances. All of the functions were implemented for use by novice users with the help of a menu tablet.

The follow-up versions of the system included more advanced functions, such as the generalization of lines based on the fractal dimension, and Minkowski's elastic space-distance non-Euclidean geometry functions (Siekierska and Taylor 1991).

E. Original contribution.

The 1983 paper introduced the concept of an analytical electronic mapping and publication system (GWS) and termed it an electronic atlas. In the next several sections I highlight significant aspects of that original contribution to achieving synergy between classical and modern cartography and geovisualization.

E1. Development of the concept of an analytical electronic atlas.

The new concept introduced in the 1983 paper was that of an electronic atlas. Later, this term was used by many national mapping organizations and cartographic centres around the world (Rystedt 1997). The electronic atlas could be defined as a systematic collection of digital maps designed for distribution online, or through other electronic media such as CD-ROMs (Siekierska 2014).

Electronic atlases range from “read only” which display ready-to-use maps, to “user generated atlases” or “mapping on demand” where the system has stored boundaries and thematic attribute data, and the user can generate the required maps. The most advanced and versatile systems were later classified as an analytical electronic atlas, which could display ready maps but could also enable access to the database for users to generate new information using analytical functions (Siekierska 1990b). The electronic atlas exemplified in the GWS was in this category.

Over time electronic atlases have been referred to in various ways, including hypermedia atlases (Armenakis *et al*., 1992), multimedia atlases (Guay 1992), CD ROM atlases (Benmouffok *et al*. 1884), Internet-based atlases (Siekierska and Armenakis 1999), and cyber atlases (http://sikuatlas). The basic functions were similar, and the names emphasized the media and technology used for distribution. With the steady growth of geospatial information, electronic atlases were also considered as gateways to National Geospatial Data Infrastructures (Morrison 1995).

E2. Hybrid raster and vector mode processing of cartographic data.

The optimization of processing in the GWS system was achieved through use of a dual mode of data handling, namely the raster and vector modes. In the 1980s raster processing was primarily used in remote sensing and vector processing in computer-assisted cartography (Huang et al. 1990). The use of both within one system resulted in a wide range of functionality (Siekierska 1980). The efficiency of processing was achieved through the implementation of each function based on the inherent characteristics of data, type of analysis, and methods of interaction, processing, and display.

One of the technical innovations introduced in GWS data structures was the subdivision of large raster files into smaller units called “mapels” (map elements) and the indexing of features present within each “mapel”. This allowed users to by-pass irrelevant “mapels” during the processing. The optimization of processing was an important factor when handling raster data on small computers.

E3. Implementing cartographic theory of the visual thresholds generalization in the computer environment.

The new field of automated mapping needed strong theoretical foundations. One of the theories that had an extensive impact on the effective display of geospatial information was the visual thresholds generalization. It was formulated in the 1970s by Professor Lech Ratajski (Ratajski 1973; Siekierska 1984) and adapted to the computer-assisted environment in the GWS system. It was only in the computer-based environment that the broad impact of this theory could be fully recognized. Presently, most of the cartographic systems which have “zoom in and out” functions take advantage of the cartographic rule introduced long before the automated systems were available.

E4. Hybrid cartographic mapping system.

GWS, later referred to as the Electronic Atlas Mark I and the Electronic Mapping System (Siekierska and Taylor 1991), was in the category of hybrid cartographic and GIS-type systems. It included an authoritative collection of maps, *i.e.*, “an atlas”, but it also permitted access to the databases by the users who were interested in performing analysis and designing maps themselves. The category of cartographic mapping system was distinct from GIS through its focus on effective cartographic communications, whereas in GIS the focus was on analysis and the visual representation of results was not a priority.

F. Derivative attributions.

The name "electronic atlas" was inspired by the electronic charts developed by the Canadian Hydrographic Service, Department of Fisheries and Oceans, Government of Canada.

A focus on raster mode processing was suggested by Prof. Dieter Steiner, an early promoter of my Ph.D. thesis at the University of Waterloo, which was later completed as Dr. of Natural Sciences at the ETH-Zurich in Switzerland (Siekierska 1980).

The visual thresholds generalization theory was formulated in the 1970s by Prof. Lech Ratajski (Ratajski 1973). This theory advocates the conversion of type of symbol when, during the scale reduction or enlargement process, a visibility threshold has been reached; for example, the conversion of area symbols into point symbols when an area becomes too small for acceptable legibility.

An important concept inspired by the 5th edition of the National Atlas was the derivation of all map scales from one data source, and the newly defined federal geospatial platform (FGP) (Groot 1979). The electronic atlas, as implemented in the GWS, advocated the derivation of various scales of display from one single database. The principles were similar to one of the rules of the federal geospatial data infrastructure (FGDI) (Groot and McLaughlin 2000), namely, “data collected once closest to the source,” which attempts to integrate all geospatial databases within one national database. Thanks to increasing cooperation and collaboration between federal, provincial and territorial governments, facilitated by common interests and the swift Internet as well as by standardization of data exchange, the goal of integration of digital geospatial data and reduction of duplication of efforts is coming closer to a reality.

[Editor’s note. While reviewing this part of the paper I was puzzled by the word “once”, which makes no sense whatsoever to me unless the totality of Canada’s natural and built environment and everything associated with those environments becomes permanently frozen in space and time at the moment that observations are made. To relieve my puzzlement, I sought advice from Gordon Plunkett, Esri Canada, who is most knowledgeable in such matters. I am grateful to Gordon for directing me to the context for the rule referred to by Dr. Siekierska. The rule may be derived from the proclamation, “Fundamental geographic data of choice for Canada – collected once, maintained and available without restrictions***”,*** which appears on the cover page of the document, *GeoBase Principles, Policies and Procedures,* published by Natural Resources Canada, and dated July 27, 2008. The publication can be viewed at https://www.google.ca/#q=Geobase+PPP. Upon examination of the document I am in agreement with my initial assessment, namely, that the word “once” does not make real world sense in any way, shape, or form. I suggest that the appropriate term is along the lines of “as needed”, and I urge that this correction occur at the earliest moment.]

G. Impact.

The AutoCarto Six paper (Siekierska 1983) was re-published in *Cartographica* in 1984. This re-publication significantly increased the visibility of the concept of an electronic atlas. Further, the paper “Electronic mapping and electronic atlases: New cartographic products for the Information Era – The electronic atlas of Canada” was an invited publication contribution to the Canadian National Report for the 1991 ICA conference (Siekierska and Taylor 1991).

The term “electronic atlas” and the key concepts were very popular for the next fifteen years; however, other terms such as “hypermedia”, “multimedia”, “visualization”, “Internet-based” and “cyber” became widely used as atlas descriptors as well. This change in terminology reflected rapidly changing technology, and a tendency to be innovative, up-to-date, and progressive (Armenakis et al. 1992; Siekierska 1993a and 1993b; Siekierska and Williams 1996; Siekierska and Armenakis 1999).

G1. Impact in the international community.

The concept of electronic atlas was introduced by the author to the international cartographic community at the International Cartographic Association (ICA) conference in 1987 (Rystedt 1995). It was readily accepted in several counties, and was a high priority item on the agenda of the ICA commission on National Atlases (in 1991 renamed the National and Regional Atlases) for several years. At the 1989 commission meeting the author was invited to Co-Chair the commission, and was involved in co-organization of several conference sessions and seminars devoted to electronic atlases.

Separate sessions devoted to electronic atlases were organized at the ICA National Atlases commission meetings, and ICA and IGU (International Geographical Union) conferences in 1989 in Stockholm and Kiruna, Sweden; in 1990 in Beijing, China (Trainor 1990; Siekierska 1990b); in 1991 in Leipzig, Germany and in 1992 in Madrid, Spain (Fernandez and Sanz-Cruzado 1993; Siekierska 1992). A special session on "Electronic Atlases: National and Regional Applications" was held at the 1994 ASPRS/ACSM Annual Convention in Reno, Nevada, USA (Rystedt 1997).

The first seminar devoted to electronic atlases was organized in 1993 at the Eoetvos Loran University, in Visegrad, Hungary, (Klinghammer *et al*. 1993). The second seminar entitled: "National and Regional Atlases in new Environment: From CD-ROM to Internet" was organized at the Charles University in Prague, Czech Republic, in commemoration of the 640th anniversary of that university (Koebben et al. 1997; Siekierska and Williams 1997). Additionally, a one-day Symposium on "Electronic Atlases – a New Way of Presenting Geographical Information" was held in conjunction with the IGU 28th Congress (Koebben *et al*. 1997). The third seminar was organized at the University of Iceland in Reykjavik (Gylfason *et al.* 1999)

These gatherings and the publication of proceedings further promoted the consultation on various concepts for development and publication of electronic atlases and related cartographic products and electronic mapping systems (Siekierska 1986, 1987, 1989, 1993, 1993a, 1993b, 1994a and 1994b, 1996).

G2. Impact in Canada.

The GWS (Electronic Atlas Mark I) was further developed in the Electronic Atlas Mark II and III and served as a proof of the viability of the concept. In the National Atlas of Canada program the focus of activities shifted to the Internet- based National Atlas Information System – NAIS (Siekierska and Williams, 1996). However, several electronic atlases were published by the Canada Centre for Mapping and by private industry. For example, the CD-ROM "Historical Evolution of Canada" was developed to celebrate the 125th anniversary of Canada (Armenakis and Siekierska, 1999). The web-based "Visualization of Nunavut" published to celebrate the creation in 1999 of Canada's newest Territory, and "Spatial and Historical Evolution of Iqaluit", (first Natural Resources Canada 4-lingual web site (Inuktitut, Inuinnaqtun, English, French), and recently transferred to the Nunavut Research College [http:test1.webapptesting.net), are examples of more recently-developed electronic atlases.

An interesting electronic atlas was developed by the Canada Center for Remote Sensing. The atlas was titled "ELADA 21: Electronic Atlas of Agenda 21 - Biodiversity Volume". It was produced in collaboration with the International Development Research

Centre, the private company (LMSOFT), and the Canadian Biodiversity Informatics Consortium. The Bahamas, Canada, Costa Rica, Kenya, Poland, and Thailand, and international organizations, such as the World Conservation Monitoring Centre and the World Resources Institute have contributed to ELADA 21 (Benmouffok et al. 1994).

Another innovative atlas also produced by the Canada Centre for Remote Sensing and the Canadian Space Agency, as Canada's contribution to the International Space Year 1992, was *GEOSCOPE - Interactive Global Change Encyclopedia*. The collaborating federal government departments included: Agriculture, Environment, Fisheries and Oceans, and Secretary of State. *GEOSCOPE* was designed to give access to vast data and image databases, and as a tool needed to analyze the data and images (Simard 1992).

In 1998, a review of thirty electronic atlases on CD ROM from the collection of the GeoAccess Division of the Mapping Information Branch, NRCan, was published as an internal report (David 1998).

H. Conclusions.

Writing a retrospective is challenging but very rewarding at the same time. The main challenge was that the author did not continue to work in the field of electronic atlases. Therefore, this retrospective paper covers primarily the first fifteen years of development. To write a complete thirty years retrospective, it would be essential to do a thorough comparison of technology and its use between the years 1983 to 2013, as well as to conduct a thorough review of the electronic atlases and related cartographic visualization products developed world wide in these years. Due to the other commitments, it was not possible to so this within the period of time available,

The 1983 paper provided only a glimpse of capabilities which computer- assisted systems and products provide at the present time. However, it indicated quite well the direction which the field of computer-assisted cartography and geovisualization would take, predicting the increasing interactivity, analytical capabilities, and accessibility of electronic atlases, systems, and products.

Today, even rare historical atlases such as Mercator World Atlas have been converted to a digital formal (Octobi edition) and thus made available to wider audiences. Another trend is to integrate the electronic atlases into multimedia encyclopedias (such as Frolier's Multimedia Encyclopedia), or into digital libraries (such as Microsoft Encarta Reference Library). This trend will continue as more and more geospatial information becomes available to household or individuals via wireless tablets and cellular phones.

I. Acknowledgement.

The author wishes to acknowledge the strong dedication of Professor Barry Wellar, editor of the AutoCarto Six proceedings and the *AutoCarto Six Retrospective*. Publishing a thirty-year retrospective book was the idea of Barry, and his contributions

to this paper are greatly appreciated. It was a brilliant idea to revisit the past. In our continuously accelerating world the time and space for reflections are frequently missing, particularly in decision making, resulting in not fully informed decisions or duplication of efforts. It is only when we understand past developments that we benefit from the research conducted before our time, and make solid, well-informed decisions about new directions. The publication of *AutoCarto Six Retrospective* bodes well for the future of the fields of cartography, mapping or geovisualization, and remote sensing or Earth observations.

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Moonshot – USGS and Census Build TIGER

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ABSTRACT. In 1983 GIS technology was rapidly developing on many fronts. However, data to use within GIS were in short supply. National data bases with any level of detail were non-existent. In an unprecedented display of collaboration, the U.S. Geological Survey and the Bureau of the Census agreed to construct a national dataset of transportation and hydrographic features that would be used in conducting the 1990 decennial census. Each agency devoted significant resources to the task and achieved this ambitious goal. The 1990 TIGER data base that resulted from this effort became the “fuel” that energized the subsequent GIS development and adoption revolution.

KEYWORDS. Census Bureau, decennial census, digital cartographic data bases, GIS, national data base, NHD, TIGER, USGS, technical innovations, linkages.

A. Title of AutoCarto Six paper.

An intermediate-scale digital cartographic data base for national needs.

B. Reason for paper.

The AutoCarto Six Symposium served as the venue for the U.S. Geological Survey (USGS) and the Bureau of the Census to announce to the professional community our intent to create a national data base of transportation and hydrography features commensurate with the content of the 1:100,000-scale USGS topographic maps. Adding to the difficulty of the task, the USGS component needed to be completed within five years to allow Census time to construct the TIGER files for the 1990 decennial census.

C. Thoughts shaping the design of the 1983 paper.

We wanted to show that we could use the power of digital cartographic data to fulfill the information needs of a major data user (the Census Bureau) to meet a national goal (the enumeration of the 1990 decennial census). The paper showed that we had laid the groundwork for the project years earlier in the graphic design of the 1:100,000-scale topographic maps.

By the early 1980s the technology had matured to a stage where we believed that thousands of maps could be digitized, edited, structured, and entered into a data base.

With a major data user irrevocably joined with us, we had a *raison d'être* to redirect programs and resources to achieve the seemingly impossible time deadline of five years for project completion.

What the paper deliberately did not discuss was that the project did not have unanimous support in either agency – in some factions far from it.

The project would not have succeeded without the leadership of Rupe Southard and Lowell Starr of USGS and Bob Marx of Census. These individuals ensured that their organizations remained committed to the project for seven years, an eternity in the Federal government environment. They risked their professional stature, and indeed their jobs, on the success of the project. It is safe to say, given the environment in federal government, that this project could not and would not be undertaken today.

D. Impacts.

The broad impact this project had on the GIS field is almost impossible to summarize. Suffice it to say, that had the project not succeeded, the evolution of the GIS field in the 1990s would have been drastically different.

For example, firms such as Etak (now TeleAtlas/TomTom) and NAVTEQ (now Nokia) began with the road networks as shown on USGS maps and attributed by TIGER. In essence, these firms received, for free, data that cost over $300 million to acquire. Without this boost from the government, it is difficult to see how either firm would have been viable.

Consider the subsequent activities that created the current location-based services, Google maps, etc. Would they have come into place without TIGER? Probably they would have, but their development and introduction would have occurred under a drastically different set of conditions.

From a GIS user point of view, without TIGER many GIS projects would have been impossible to pursue, data infrastructures would not have been constructed, and spatial data analysis would have languished.

Somewhat perversely, the project's success began a long, slow decline in federal topographic mapping in the U.S. Unfortunately, in the early 1990s USGS failed to build upon its success with the Census, and returned to its "traditional" mapping programs.

By the time USGS finished with the "one-time" coverage of the country with 1:24,000-scale topographic maps (in 1992), the level of support for mapping had started to wane.

Today, the agency does not conduct a national topographic mapping program.

E. Conclusions.

The national data bases of transportation and hydrographic features, begun in 1983, are still utilized today. Census continues to maintain and enhance TIGER. In each of the last decades, major efforts were made to improve the quality of the data and update features for use in the 2000 and 2010 decennial censuses. USGS, in collaboration with the Environmental Protection Agency, has continually refined the hydrographic data.

The National Hydrography Dataset (NHD) contains surface water features with flow network relationships that allow for tracing water downstream or upstream (see http://nhd.usgs.gov). NHD uses an addressing system based on river reach codes and linear references that allows for linkages to specific information about the water such as water discharge rates, water quality, and fish populations. Census uses a simplified version of the NHD for the hydrographic features in TIGER.

Thirty years ago in the autocarto/GIS field, U.S. federal government agencies were sources of technical innovations as well as primary data producers of digital data. Today that role seems to exist primarily in the private sector.

This is not an environment that favors innovative thinking on the part of government scientists to create a “big idea” for the common good of the public.

While it saddens me to think that the project to build TIGER would not even make it onto the drawing board today, I am glad to have been a part of the team that made this project a reality.

It is a fitting legacy that the project and its echoes continue to shape the GIS landscape.

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Reflections on Data Transfer between Software Environments and the Challenges of GIS Teaching in a Post-Secondary institution

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ABSTRACT. Thirty years is a significant period in the software development field. In 1983 we focused on data transfer between the image processing and the geoprocessing environments. At a small technical institute it was important to optimize these two mini-computer based technologies. In 1983 these tools were specialized and less readily available; this provided us with the context for collaboration between the institute, the vendors, and various government agencies. Today there are similar challenges, intensified by both the web and mobile GIS space. This is coupled with the increased demands from 'citizen' science. To meet the new goals, we see a return to co-operative projects as a mechanism for shared learning. While the vendor landscape has changed dramatically, the complexities of the learning process remain either constant or even more challenging.

KEYWORDS. Data transfer, GIS, image analysis, training geo-specialists, COGS, co-operative projects, technology changes.

A. Title of AutoCarto Six paper.

Two way data transfer between Aries Image Analysis System and Arc-Info Geographic Information System.

B. Reason for paper.

In 1983, the authors were instructor and student in a specialized one year advanced diploma program in Scientific Computer Programming at the Nova Scotia Land Survey Institute (NSLSI). Part of the program was a cooperative project with industry and government agencies. We had recently acquired the Esri Arc/Info (version 2.1) GIS running on a Prime computer, and we were using the DIPIX Aries II system running on a DEC computer for remote sensing. The obvious challenge was to be able to efficiently move raster imagery from our image analysis environment to the GIS, and conversely, vector data layers from our GIS environment to the image processing world. The paper addressed a technical solution to this challenge and provided a sample application of how it was used.

C. Changes in the institution.

The authors were actively engaged in the transition of NSLSI into the College of Geographic Sciences (COGS). Between 1980 and 1986, new programs in Computer Graphics and Geographic Information Systems were added to existing programs in Cartography, Planning, Remote Sensing and Surveying. COGS evolved along a similar path as Sir Sandford Fleming College (SSFC) in Ontario, the British Columbia Institute of Technology (BCIT), and the International Training Centre (ITC) in the Netherlands.

Today, the Centre of Geographic Sciences (COGS) is a component of the Annapolis Valley Campus of the Nova Scotia Community College (NSCC), offering one-year Advanced Diploma programs and two-year Diploma programs in Geographic Sciences. The entry requirement for the Advanced Diploma programs is an undergraduate degree from a recognized university.

In terms of curriculum in 1983, both GIS and image analysis were considered to be exciting environments for software development. Today, the emphasis is more on the application of these tools, rather than writing code to enhance functionality. In 1983, every student completed a project with industry or government; as instructors, we had direct contact with the programmers and software designers in these companies. Over time, many of them were our graduates.

D. Changes in technology.

In the early 1980s, the COGS computing environment was mini-computers. Later, we adjusted to the micro-computers. Today, we have server technology and access to the cloud. While the data transfer concepts remain straightforward, the operational needs to transfer files between different devices can be more technically challenging. We have new remote sensors, e.g., LiDAR, and *in-situ* networks, as well as a plethora of hand-held devices, e.g., mobile phones operating within a web-enabled world.

E. Changes in industry.

In the 1980s there were two solitudes between image analysis and spatial analysis. While there was recognition of the value of imagery, it was not a core component of the visualization process. Eventually, there were changes in the Canadian industry; we lost DIPIX and TYDAC. In the United States, Esri formed an alliance with Erdas. The collaboration was slow, compared to the Canadian marketplace. Today, image processing functionality exists within the GIS system. Although there remain challenges in incorporating new data streams into GIS, e.g., LiDAR and sensor networks.

F. Changes in government.

On reflection, there have been major changes in the agencies that were part of the cooperative project network. At NSLSI (COGS) we always had projects with both the Nova Scotia Remote Sensing Centre and the Canada Centre for Remote Sensing (CCRS). Our technical graduates were sought and hired by these agencies, as well as by Ottawa-based companies. On the GIS side, we worked directly with staff at the Canada Land Data System (CLDS).

G. Changes in society.

Our work in the 1980's was pre-Internet and social media. There was not the pervasive imagery from Google or ready access. The consequences are another set of tools, which intersect with the original two software environments. While there is a heightened awareness of imagery and digital maps, the challenges for an institution, with origins in the software development world, are significant.

H. Observations on the past, and the path ahead.

A number of the design criteria for teaching GIS and remote sensing (or, generically, Geographic Sciences) remain valid today (see Maher and Wightman, 1985). It is critical to balance conceptual understanding, with practical hands-on programming and database skills, and an appreciation of the specific application domain. The idea of 'learning by doing' and the co-operative project seem to be returning to favor. We found the collaboration between industry partners, government agencies, and the instructors at the college critical and invaluable. It is interesting to see a number of institutions resurrecting this collaborative concept, whether in the university or community college (Maher 2013). Ease of transfer between different technology environments remains an important task. With the increase in both remote and *in situ* sensors for environmental monitoring, as well as human sensors, there is an increased demand for tools, which structure and validate new input streams.

I. Conclusions.

Training the next generation of technical geo-specialists will require the same flexibility and creativity that existed in the 1980's. We will continue to need institutional flexibility, small technology companies which are open to new ideas and willing to collaborate, plus government agencies with a mandate to work directly with these institutions and businesses.

We can anticipate continued pressure from citizens and grass-roots organizations for ready access to both geographic data and the tools to transfer and share this information.

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26

A Retrospective on Designing Interactive Spatial Systems Based on Real and Virtual Maps

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ABSTRACT. The 1980s was the time that the concepts of real and virtual maps, and deep and surface structure, were maturing and coming of scientific age. One could understand the insights provided by these concepts, and then their use in the process of spatial systems development. Initially they provided insights into spatial data and maps. One could then utilize these concepts to create the conceptual design of spatial data systems. This AutoCarto Six paper came during that time when they were beginning to be used for spatial data systems design. Since then the scientific work has continued to expand the concepts of real and virtual maps, as well as the concepts of deep and surface structure. These ideas are now part of the conceptual core of analytical cartography.

KEYWORDS. Interactive spatial systems, real maps, virtual maps, deep structure, surface structure, map transformations, spatial science, analytical cartography.

A. Title of AutoCarto Six paper.

Designing interactive cartographic systems using the concepts of real and virtual maps.

B. Introduction.

Three decades after publishing the AutoCarto Six paper in the *Proceedings of AutoCartoSix (Moellering, 1*983), one can now take a longer view of the paper in the conceptual flow of spatial science.

The earliest threads for this work were inspired by the work of Waldo Tobler (1961) on map transformations, and later motivated by Joel Morrison (1974) in his article in the premier issue of the *American Cartographer* where he challenged researchers to expand the scientific definition of a map in a systematic way. Earlier work by Riffe (1970) called spatial screen displays "temporary maps". Other work talked about the notion of "ephemeral maps". Both descriptive labels of these new map forms was very unsatisfying because they were not based on the scientific characteristics of maps, some being hard copy, some being screen displays, and some being spatial data bases. The need was for a universal scientific definition of maps.

Moellering (1977) had been working with interactive spatial systems during this time, and was thinking more deeply about this concept of how maps should be defined.

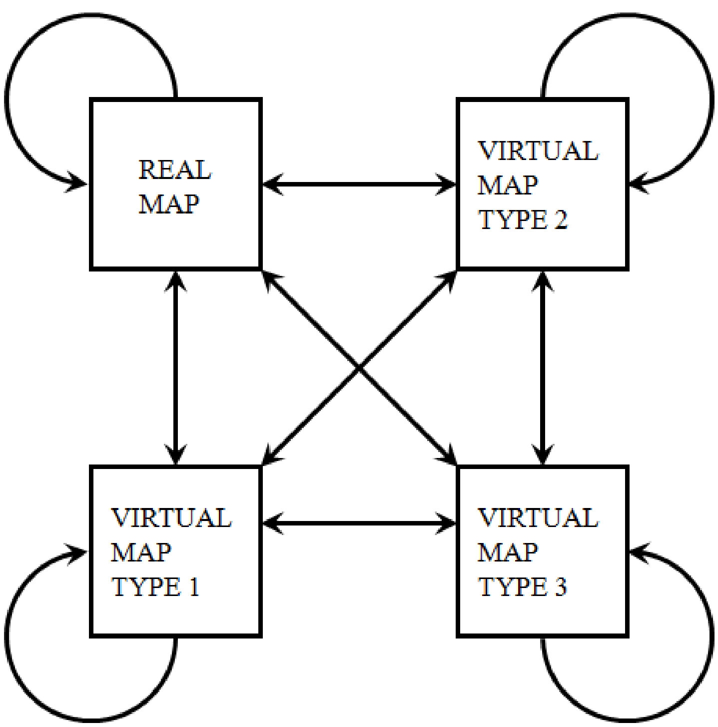
The goal was to develop a comprehensive scientific definition of a map that was exhaustive in all forms of maps: screen displays, hard copy maps, spatial databases, mental maps, etc.

It became apparent that the two primary characteristics that emerged were whether they were hard copy (yes/no), and whether the information was directly viewable as a graphic image, screen display, spatial database, or perhaps hard copy (yes/no). The first article appeared in the *Cartographic Journal* (Moellering, 1980) with four classes of real and virtual maps with 12 transformations between them. It also became clear that these transformations could be used to better understand spatial data processing and utilization, as well as using them to assist in the design of spatial data systems.

C. The AutoCarto Six contribution.

The paper presented at AutoCarto Six was a footprint along the trail of conceptual development of the concept of real/virtual maps, their transformations, and their utilization in the design of interactive spatial systems. Among other things, this paper recognized the need to expand the number of map transformations from 12 to 16, thereby including things like virtual 3 to virtual 3 transformations which include spatial database transformations and real map to real map transformations (conventional hard copy cartography). Figure 1 shows the updated 16 real/virtual (R/V) map transformations.

Figure 1. The 16 transformations between real and virtual maps.



In my classes in numerical and analytical cartography I stated that these 16 R/V map transformations could be utilized to model any spatial data process, whether it is spatial database conflation, interactive image processing, or map reading and perception. I challenged my graduate students to define a spatial data/map process which could not be modeled by one, or a combination of, these 16 R/V map transformations. I added an incentive by telling the graduate students that if they could find an example spatial process that could not be modelled with these 16 transformations, I would buy them a pitcher of beer on the next Friday. In more than 30 years of such classes, I never had to buy anybody a pitcher of beer.

The AutoCarto Six paper was the first place where the Nyerges (1980) concept of deep and surface structure of spatial data was blended in with the concepts of real and virtual maps and their transformations. Nyerges had developed the concept of spatial deep structure in his dissertation by extending the work of Noam Chomsky (1965) from the conceptual theory of structural linguistics. This blended very well with the R/V map concept because the graphic visualizations, screen display or physical map, are surface structure, while spatial data in the digital domain, and their relationships, are part of the deep structure.

Also included in the paper was a generic logical design diagram of a spatial system that showed the basic R/V transformations being utilized in the system and its user. Further examples using these transformations were a general workstation layout, and a logical command structure for a small spatial data analysis and display system. Interestingly, although the hardware layout for the spatial work station is somewhat obsolete, the R/V map transformations are still perfectly valid. This is in line with Tobler's concept of the half-life of theory versus the half-life of technique, where the conceptual theory continues to live on far beyond the technique. Although the technique is aging, the conceptual R/V map transformations being utilized are as valid as ever.

D. Updates and extensions.

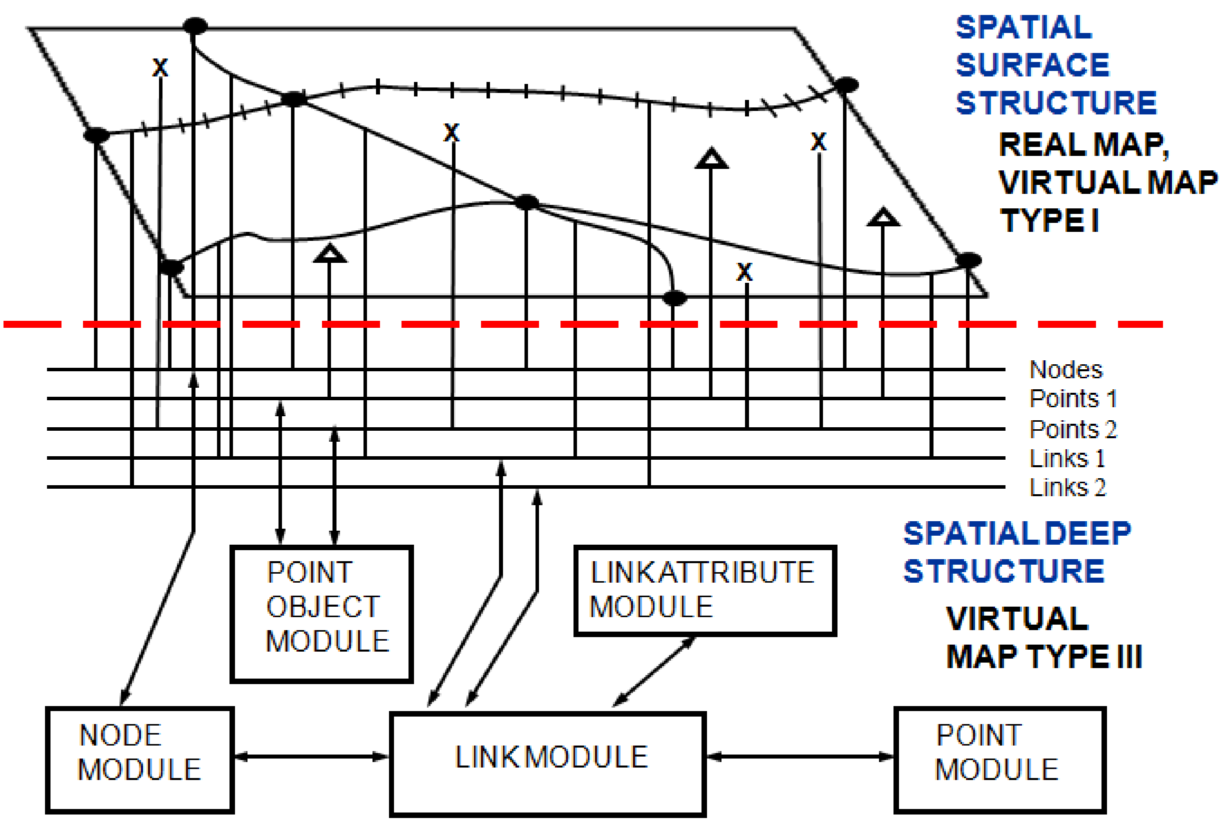
Nyerges continued to flesh out his deep/surface structure work from his dissertation. Throughout the centuries of cartography and the spatial sciences from the ancient Babylonians, Greeks and Egyptians onward, most all maps and spatial displays have been direct surface structure. There were a few books and compilations of spatial data which one could classify as deep structure, but the overwhelming emphasis was on the graphic surface structure visualization.

In the last century or so with the rise of digital systems, the quantitative and qualitative data in the deep structure has been growing immensely. Directly stated, Nyerges' work on deep structure has led to the recognition of the new half of our fields in the spatial sciences.

He has also conducted some work on analytical map use (Nyerges, 1991) which discusses how some entity class types relate to virtual 3 maps in the deep structure. This can be visualized in Figure 2 which shows a virtual 3 database in the deep structure. This is where the syntactic and semantic relationships can be analyzed in the spatial data. This kind of activity usually takes place in some kind of spatial data system, which interactively generates displays during various stages of processing, up to the final result.

In many cases, there are repeated interactions between the virtual 3 spatial database which is being processed, and the virtual 1 screen display. This kind of interaction is regarded as the heart of an interactive spatial data analysis system.

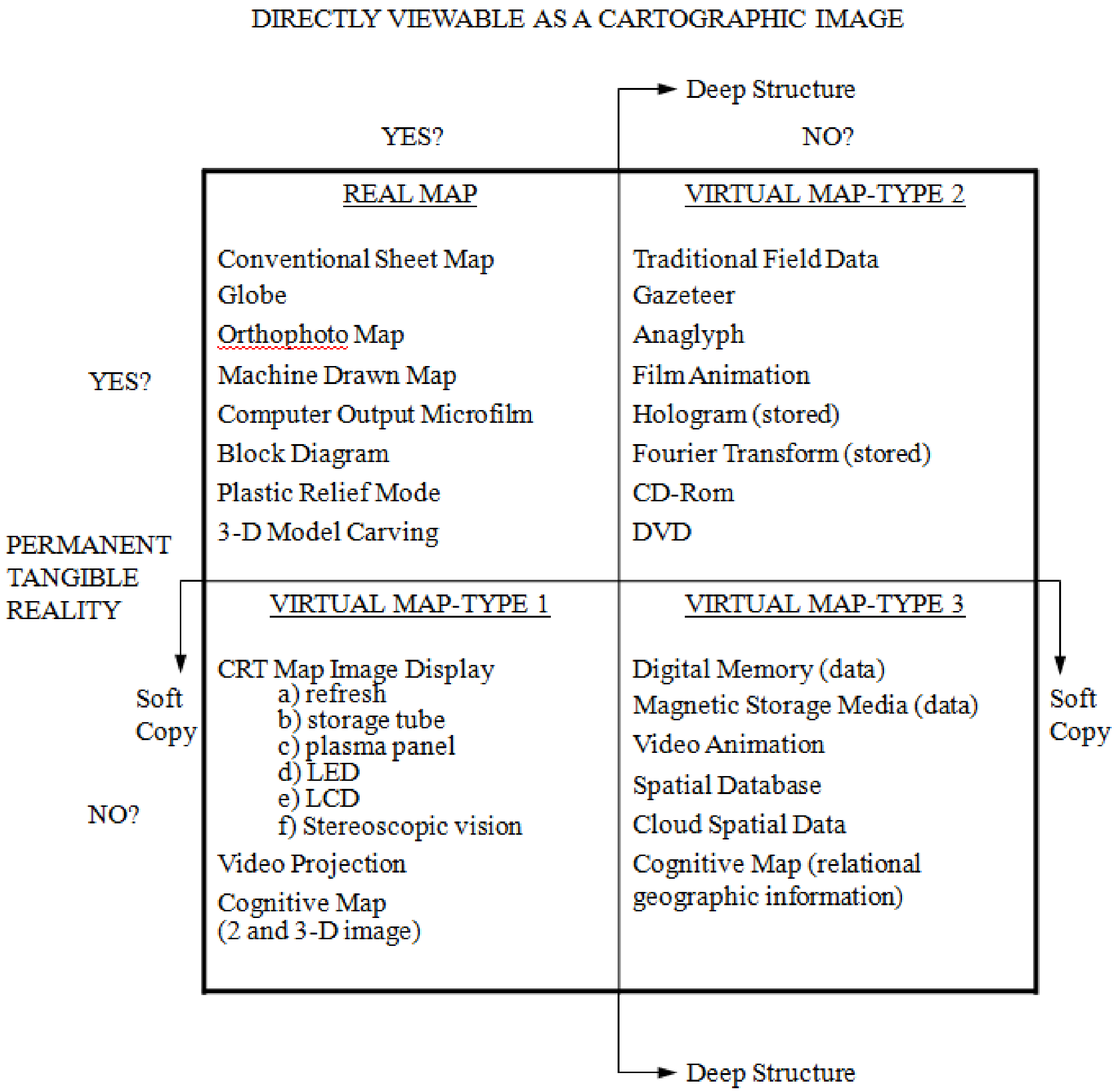
Figure 2. Representation of deep and surface spatial structure.



One can further refine the real/virtual map concept and combine it with the Nyerges deep/surface structure and the photogrammetrists' concept of hard and soft copy, as shown in Figure 3.

Every kind of product in the spatial sciences can be classified into the four class real/virtual map concept with two sharp binary yes/no answers to the questions of hard copy and direct viewability of the spatial visualization as discussed by Moellering (2007).

Figure 3. The scientific definition of real and virtual maps.



E. Future Work and Inspiration.

It is clear from the above discussion that these concepts of real and virtual maps, deep and surface structure are very important when it comes to conceptualizing and designing interactive spatial data processing systems. It is also a central part of the field of analytical cartography itself (Moellering, 2000).

However, it is equally clear that much more use could be made of these concepts to flesh them out further, and to more concisely develop the linkages between real and virtual maps and deep and surface structure. There is clearly more to be accomplished in terms of fulfilling some of the research needs in this area as discussed by Moellering (2001).

It is also clear that more practical implementations are possible with spatial systems design tools, as these concepts provide a clear insight into the basic functionality of such a system. Sometimes system designers get lost in the design forest because of the implementation trees, and these concepts help to maintain an overall vision of the system. Interestingly, these concepts can also be applied to more detailed subsystems down to the finest scale cursor click in the system.

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27

Big Data: How Geo-information Helped Shape the Future of Data Engineering

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ABSTRACT. Very large data sets are the common rule in automated mapping, GIS, remote sensing, and what we can name geo-information. Indeed, in 1983 Landsat was already delivering gigabytes of data, and other sensors were in orbit or ready for launch, and a tantamount of cartographic data was being digitized. The retrospective paper re-visits several issues that geo-information sciences had to face from the early stages on, including: structure (to bring some structure to the data registered from a sampled signal, metadata); processing (huge amounts of data for big computers and fast algorithms); uncertainty (the kinds of errors, their quantification); consistency (when merging different sources of data is logically allowed, and meaningful); ontologies (clear and agreed shared definitions, if any kind of decision should be based upon them). All these issues are the background of Internet queries, and the underlying technology has been shaped during those years when geo-information engineering emerged.

KEYWORDS. Automated mapping, remote sensing, GIS, big data, machine learning, data quality, geo-information, knowledge systems, ontologies, exploratory data analysis.

A. Title of AutoCarto Six paper.

Automatic cartography of agricultural zones by means of multi-temporal segmentation of remote sensing images.

B. Reason for paper?

In 1983, working on the above title, the purpose of my then sponsor[1] was to prepare the launch of satellite SPOT and the forthcoming commercialization of its products, with a focus on vegetation monitoring.

It may look unbelievable today, but we were not equipped with image-capable screens, only alphanumeric consoles: everything had to be printed for being displayed. However, data were there, big matrices of data, that couldn't be turned easily into images.

[1] Centre National d'Etudes Spatiales, Département de Traitement de l'image, Toulouse, France.

Therefore, we were forced to crunch data, failing to be able to look at them! The amount of images that a satellite such as Landsat was able to harvest was phenomenal: gigabytes, terabytes of pixels: we were using the super computers of that time.

Dealing with "big data" before the term was popularized? The armory of mathematical tools also was almost there: principal component analysis, multi-dimensional correlation, template matching, and so on. We may say that in remote sensing, in photogrammetric engineering, in geographical information systems, or for short in geo-information (or geomatics), we pioneered what today is termed "big data".

This paper browses the principal issues that the geo-information science had to face from the early stages on. First challenge: to bring structure to the data registered from a sampled signal, what eventually gave metadata and the ability to merge images into large retrieval systems in the Internet. Other challenges involved: processing (such huge amounts of data required big computers and fast algorithms); data uncertainty (the description of the kind of errors, and their quantification was necessary from the very beginning); data consistency (as soon as we started merging different sources of data, it became mandatory to question if and how far we were allowed to merge them. In French we say, M*ariage de la carpe et du lapin*, (Carp and rabbit wedding).

Finally, ontology questions are addressed, because the comparison of geo-data, piled up for several decades, all around the globe, imposes clearer definition on what they are data of or what they represent, what comparison can be made, what real evolution or differences they measure, and what kind of decision can we base upon them.

Today, these same longstanding issues and questions continue to be raised in the context of big data.

C. Data structure: From ancillary data to metadata.

Remote sensing imagery inaugurated the use of metadata as soon as the first images had to be registered, overlaid, and when different sensors were used.

Basically we have only two kinds of data: words and numbers. And if we have a number, we do need words too: if 24, 24 what? Natural or physical sciences deal with numbers, with signal or image processing, with geometry, time series, etc. But text processing is the main approach in big data: "*In principio erat Verbum*", the very first words of the Gospel of John. The two didn't fit well 30 years ago, but nowadays the difference is not so drastic.

Noticeably, today, is the widespread use of metadata. I do remember that we didn't use the word metadata but "ancillary data", to name the data associated with remote sensing imagery: for instance the ground resolution, wavelengths, etc. (see below). The name change denotes an upgrade for something secondary (*ancillary*) to a more important role (*meta*). The way we consider data has evolved as well.

For instance: pixel data. A pixel is the approximation of a ground surface, from which we measure a reflected (or emitted) radiometry within a certain wavelength range, integrating diffraction effect, absorption, etc. As many of us did, I spent a lot of time modeling these effects, filtering them to improve the data from a status of "raw data" to a status of "corrected data". Also, pixels aren't processed one by one, but as a statistical variable that receives class membership or geometrical properties (e.g. border pixel). These properties must be described and registered into some structure: a "processed image" has a lot of such attached information (metadata).

Libraries were confronted by the metadata issue and developed MARC in the sixties, a markup language to which HTML owes a lot. An important next step was the Dublin Core (DCMI) in 1995. In automated cartography, one big question was, How to introduce the topology in the data vector representation? It's implicit from the geometry, but the burden of re-computing it is much too heavy. Then, in the 1990s several NGOs[2] were working on what became ISO 19101: 2002 Geographic Information Reference model.

For instance, Table 1 represents the geometry and the topology of a set of land parcels and allows determining that the union of #2 and #3 forms a single hole into #1.

Table 1. A relational representation of the (polygon-arc-node) topology schema.

#	Coordinates (or vertices)	contains	is in	touches	has hole	… more …
1	*x,y; x,y; x,y ; x,y; x,y …*	**2;3**	**-**	**-**	1	…
2	*x,y; x,y; x,y; x,y …*	**-**	**1**	**3**	0	…
3	*x,y; x,y; x,y …*	**-**	**1**	**2**	0	…

The content of such tables is described in the ISO reference model: the polygon-arc-node model, with all topology relationships. Moreover, semantics and rules can be added too (See F, Data consistency.).

In big data, there are trillions of sparse, scattered, unrelated docs (unstructured) anywhere on the Internet, and the goal of so-called "robots" is to attach structure (the indexing process) and try to rank them in response to a single request (querying the Internet), or to a complex and multi-morphed request (data analytics).

The concept of unstructured data wasn't in use 30 years ago. Relational databases were just on the rise (and still are embedded in most data engineering). The term *semi-structured data* appeared in 1995 in the community of database specialists, and XML was first established in 1997 (built upon the SGML of the late 1980s).

Hence, there are reasons to consider that data processing of signal and image is one of the many precursors of today's big data.

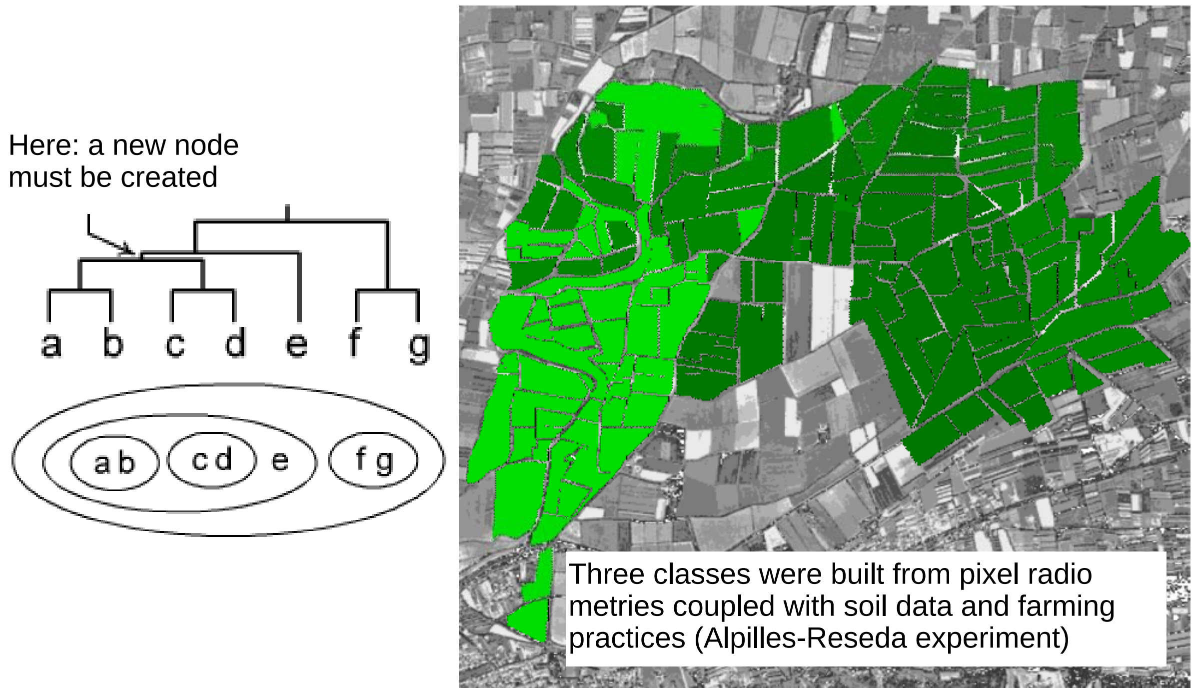
D. Data processing: From data analysis to data mining.

Signal processing has been a field of experimentation of innovative statistical, stochastic, or data transformation approaches, as well as intensive computational

[2] National geographic offices, such as Ordnance Survey, IGN Geomatics Canada, USGS, etc.

methods and efficient algorithms for the processing of very large data sets. Exploratory data analysis (EDA) is linked with Tukey and Fourier analysis and similar approaches, developed mainly in the field of signal processing. The term is outdated now, but it certainly contributed to foster research in high-end computing. Let’s recall for instance the hierarchical classification algorithms used for pixel classification in Landsat images (Jeansoulin 1981), and the use of more sophisticated approaches for unsupervised classification, such as the “dynamic clusters” (Diday 1973). Figure 1 illustrates the basics of the process.

Figure 1. Hierarchical clustering example (sometimes referred to as phylogenetic tree).



The descending operation tries to split the data domain into relevant sub-classes at each level, leading to a tree structure (See section G, Ontologies.). It is then applied to field parcels according to their median or average pixel value (Olioso 1998).

The expression *data mining* traces back to the 1990s, familiar to database scientists, and mainly as an operational approach of machine learning whose foundations are linked to the Turing machine: the field was more theoretical, between logics and computing languages, lambda-calculus. Support vector machine (SVM) algorithms were developed as non-probabilistic binary linear classifier (Vapnik 1995).

Nowadays, these terms have been more or less wrapped up in the successive buzzwords of business intelligence, data analytics, and big data. In spite of other differences, the fact is that the mainstream shifted from signal processing to the world of Internet and e-commerce.

But, looking deep into the algorithms it can be seen that: the geo-processing legacy is there. From a computational point of view (supercomputer and huge data storage), or with respect to the underlying exploratory approaches, geo-processing research has contributed to paving the way.

E. Data uncertainty: From precision to quality indicators.

Geo-information deals with the "real world": without arguing about philosophical truth, it deals at least with a same and single "world" which can be modeled and measured by different means, at different scales, from multiple viewpoints, etc., and everything has to be logically consistent.

Therefore, geo-processing talks not only about a particular aspect of reality, but also about a consistent framework for this reality.

At first, measurements quality was focused on precision: What particular location on Earth does a particular pixel represent? What is the real radiometric contribution of this location actually represented in the pixel value? Image registration, and sensor fusion, were the first and most difficult tasks at the time. Soon after that, confidence involving data classification was the big issue, e.g., *How much wheat is the USSR really harvesting*?

Questions of that nature were investigated by relatively the same amount of computing power that the NSA can harness today for processing trillions of emails.

When it became easier to merge remote sensing imagery and geographical databases, much more complex questions were at hand. The gain in ground resolution enabled us to reach new terrain: from the large rectangular crops of the Mid-West to small vineyards in Provence, and now to urban roof gardens. Sociology is no longer some weird science taught to hippies, but a science we can have trans-disciplinary talks with, as we did with agronomy.

The challenge about quality is no solely longer about data precision (though still important), but also about consistency: Are we talking about the same thing when merging different data?

Geo-processing has extensively investigated the question of quality, with the result that a number of quality indicators have been designed, and the quality domain has been structured by international consensus.

Since the 1990s, geo-information specialists met in consortia such as OGC, and eventually established an ISO Technical Committee (ISO TC211) to discuss and publish standards for geo-information (geomatics): data models and data quality information were among the most specific outcomes: ISO 19101: "reference model", and ISO 19113: "quality principles" were finally issued in 2002, reflecting common ground between the various national geographic organizations (see Table 2).

The national statistics agencies were closely working with these specialists, because the same quality issues are important for the countries and for international comparison as well. International bodies such as UNESCO, OECD, and Eurostat have also been aware of the same issue for many years, but the automation of cartography was probably among the very first pioneers.

Table 2. The actual consensus about metadata for quality in ISO19113:2002.

Data quality element / sub-element	Description
Completeness (omission, commission, logical consistency)	Presence of features, their attributes and relationships (absence or excess of data, adherence to rules of the data structure)
Conceptual consistency	Adherence to rules of the conceptual schema, to value domains, etc.
Topological consistency	Correctness of explicit topology, closeness to respective position of features
Positional accuracy	Accuracy in absolute point positioning, gridded data positioning
Temporal consistency	Accuracy of temporal attributes and their relationships
Thematic accuracy	Accuracy of quantitative attributes, class correctness

F. Data consistency: Uncertain but rational knowledge.

Understanding the many causes of data uncertainty sheds light on the many approximations made all along the process of gathering and measuring even the simplest datum: for instance, ground temperature.

Considering that data are always somewhat inexact, and considering that data always depend on a model imperfectly representing a reduced aspect of reality, it is important to provide guidelines or constraints. Every time we can provide some constraints we can confront the data, and issue a warning for each detected conflict.

Figure 2 is a snapshot of a successful experiment developed during the FP5 European project REVIG!S[3]: how to revise – by logical means and tools – very uncertain flood data using direction of water flow as constraints (Jeansoulin and Wilson 2002).

In big data, the prediction of the annual flu wave by looking through Internet “medical queries” has got a lot of media attention.

It isn’t necessarily a convincing example, but the archetypical “analytics” story is IBM Watson, when it overcomes two Jeopardy champions, in 2011. The DeepQA project behind Watson is making intense use of geo-information reasoning for answering questions such as “*They’re the two states you could be reentering if you’re crossing Florida’s northern border*" (Ferrucci 2010).

Mereotopology, region connectedness calculus (RCC) or Allen’s interval algebra [Allen 1983], developed in the 1980s, are extensively used today for constraining queries and making answers more narrow and efficient.

[3] REVIGIS project involved universities of Marseilles, Leicester, Keele, Technical Vienna, Pisa, Twente (ITC), Laval.

Figure 2. Integrating data and constraints: flow direction information and estimated water heights must comply or be "revised".

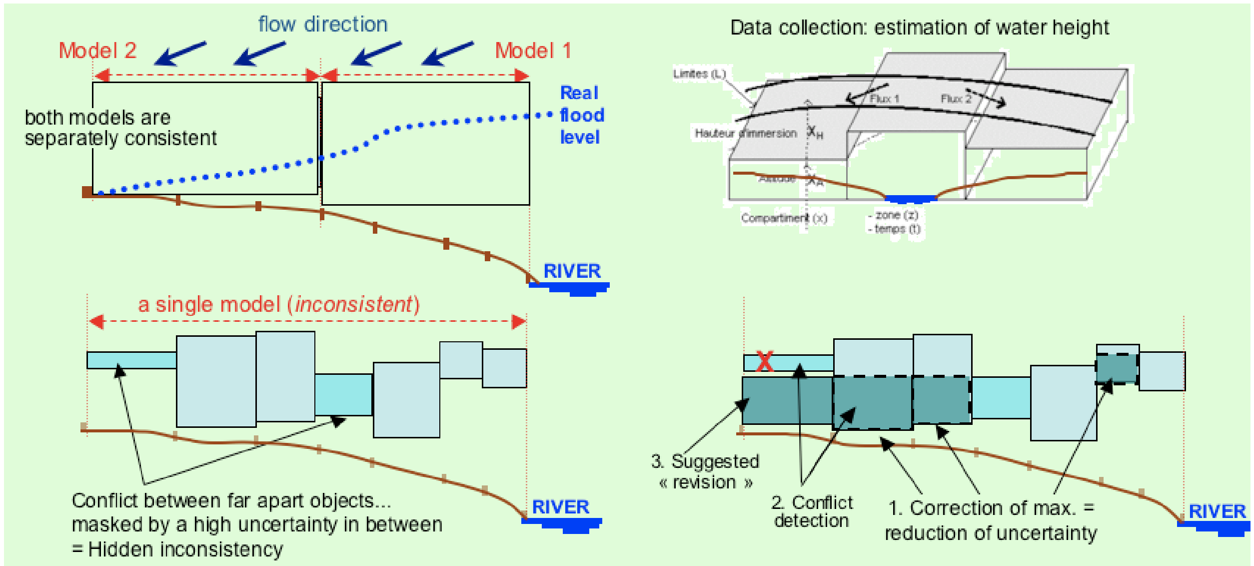
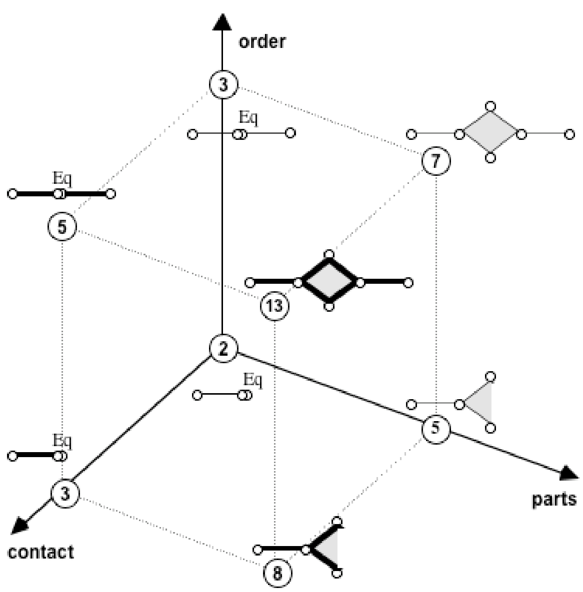


Figure 3 gives the lattice the 8 possible such algebras (Euzenat 1997).

Figure 3. Lattice of 8 mereotopology algebras.



Description. Each node gives the number of allowed relations per algebra (from 2 to 13); and the axis have the following effects:

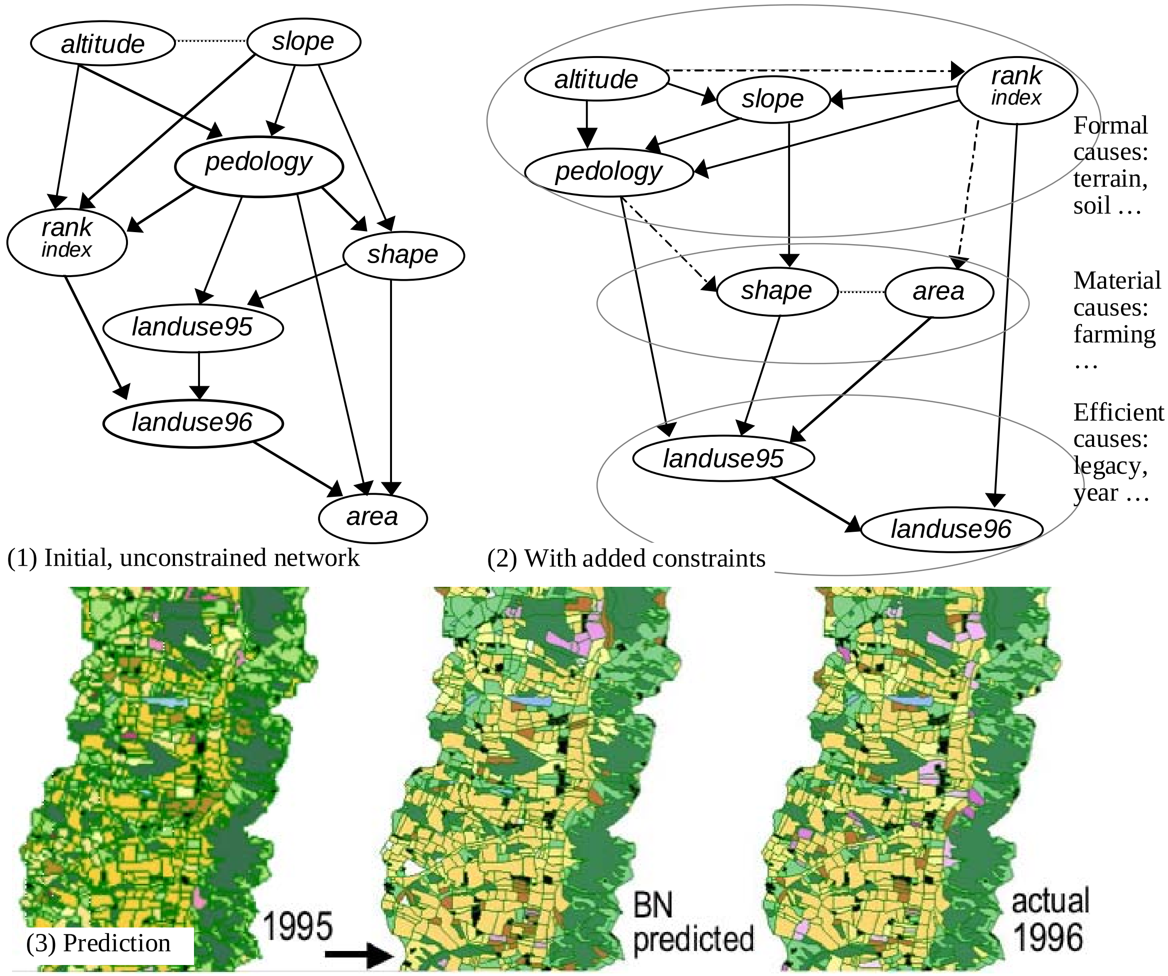
contact introduces arc (bold) relations,

parts explodes the equivalence relation Eq,

order unwraps the graph around a symmetry axis (Allen 1983).

Reasoning under constraints marries well with stochastic reasoning, as with Bayes networks (Cavarroc 2004). In Figure 4, the network (1) is the direct application of the Pearl algorithm on data (pixel data of two images 1995 and 1996, plus terrain data (altitude, pedology, etc.); the constrained network (2) accepts some additional constraints in the algorithm (e.g. slope doesn't impact the upstream/downstream rank in the valley, or landcover is not a cause for area); the constrained network is used to build a prediction (3) for the following year, from the land use in 1995 (separate data set).

Figure 4. Bayes networks used in prediction mode.

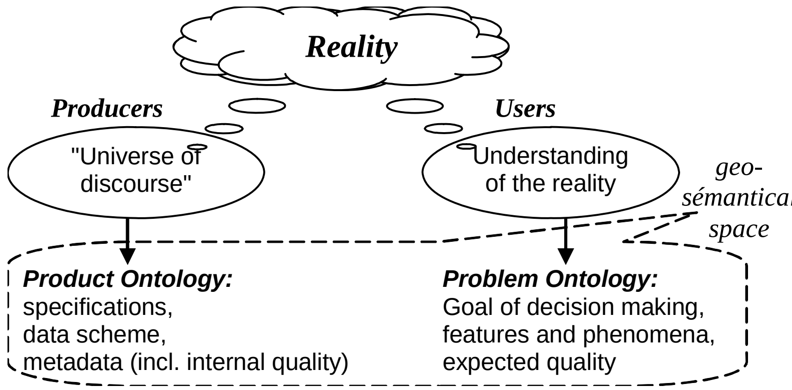


G. Ontologies: Data are acts, not facts.

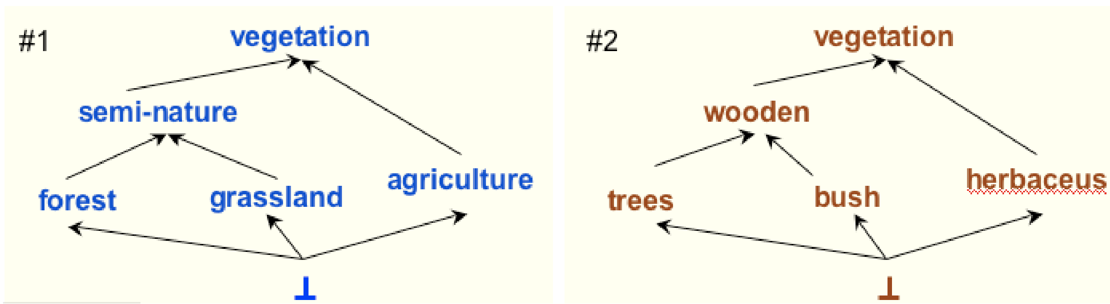
Geo scientists are still classifying and zoning, but much more attention is turned to the meaning of the process, the interpretability of the result, and the ability to use it within a decision process. Moreover, geo-information also raised the question of what is in data, common agreement, external quality, data usability, etc., which are different aspects of a more general question often summarized into the word "ontologies" (plural!), and the subsequent problem of "ontology alignment" (Gruber 1994; Halevy 2005).

Here again, the terminology has been brought to public attention by the wide spread of the Internet and the mainstream studies following it, but, here again, geo-information was developing its research when questioning the problems of global data quality, of managing different quality levels for different types of information, and geomatics was among the first to provide a systematic and comprehensive approach, with the above-mentioned ISO 191xx series of standards, in particular in 2002 with ISO 19150 ("ontologies"), and ISO 19157 ("data quality"). Deviller and Jeansoulin (2006) regroup a good part of this research on ontologies and quality, in particular the notion of external quality (quality for the user) which is illustrated in Figure 5, where the quality defined by the producer of geo-data is internal (referring to its own specification) rather than external (quality as a fitness for use).

Figure 5. The internal versus external quality issue.



Let's develop an example of ontologies alignment with agricultural data. Given 2 graphs representing two different surveys of the same region (Pham 2004), the observations at

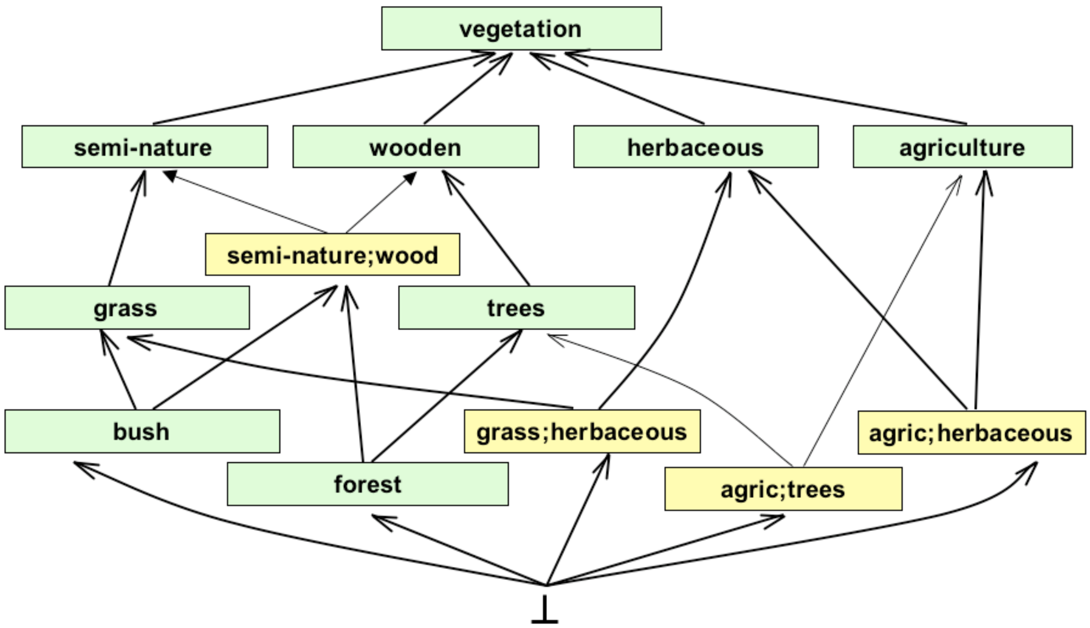


the same locations (parcels) will differ according to their ontologies, and we can build a Galois lattice summing up the fusion of information.

In Figure 6, the conflated graph contains all the different nodes of both initial graphs, plus some additional mandatory nodes (yellow), minimal addition for a consistent fusion, and whose labels are a consensus between the two original ontologies, e.g. "(grass; herbaceous)". This consensus between the two ontologies is minimal, in that it is much more efficient and meaningful than the mere cross-product of the two ontologies.

Therefore, ontologies are not made solely for Internet applications or e-business, but also for addressing real world queries: "*What there is*", or "*The nature of being*", as discussed by the philosopher W. O. Quine and others with an interest in ontology as a branch of philosophy which deals with the science of what is, what exists, and associated concerns. These fundamental questions have confronted geo-information scientists since the beginning of their work.

Figure 6. Consensus graph for the fusion of the two ontologies.



H. Conclusion.

Some 30 years ago, the conjunction of the multiplication of remote sensing imagery (Landsat 1976, then SPOT), the early stages of desktop image processing, the automation of the cartographic processing, and a rapidly increasing computing power – *doubling every two years* according to Moore's law, version 2 – offered an opportunity to collect, merge, and process an enormous amount of data, an amount larger than that ever collected and processed by machines.

The engineers and researchers involved in geo-information were, consequently, on the leading edge for the development of tools and methods that eventually are part of what today is termed big data.

Finally, in closing, a tribute.

It is appropriate to recognize the expertise that geo-information specialists have developed in data engineering. Decision-makers are increasingly relying on numbers to prepare and make their decisions. However, it appears that few of them are aware of the way these numbers are produced, that is, data are the result of many small decision-making processes at all stages. Data are not Facts, but Acts.

From the signal to the semantics of information, the science of geo-information has confronted, and been confronted by, a very large range of issues, and has brought its contribution to many data models, and many algorithms.

Dealing on an everyday basis with data and models, but dealing basically with the real world, the geo-information scientist must continue to seek out the right tools and representations, and thereby continue to pioneer advances in data engineering.

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Human Factors in the Design of Real-Time Cartographic Displays – A Battle Lost?

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ABSTRACT. Cartography seems to have been replaced by GIS, but the skillsets and knowledge of cartographers seems not to have informed the many organizations that are responsible for the maps that we use today. In part, the world of map-making and display design have crossed a chasm, with the spatial data sciences on one side and, on the other, the commercial organizations willing to satisfy the public's immense appetite for maps that are focused on users and the geographical opportunities that surround them during their daily life.

KEYWORDS. Human factors, display design, GIS, real-time map use.

A. Titles of AutoCarto Six papers.

Human factors in the cartographic design of real-time cartographic displays; and, A high resolution microcomputer-based color system for examining the human factors aspects of cartographic displays in a real-time user environment.

B. Reason for papers.

My intent for the 1983 presentations was to describe the challenges surrounding the design of maps when using computer displays for spatial problem solving. At that time, the literature in human factors had not yet progressed to examining display with the level of complexity of commonly used maps. Conversely, few cartographers had substantive understanding of human factors in display design or the types of questions that would come to plague the success of cartographic communications in a world where color, real-time map display would be increasingly common.

C. Thoughts shaping the design of the 1983 papers.

It had been my general experience that we knew little about the complex information transfer process that occurred while persons used maps. It was, also, clear to me that the paper map, while still not quite at the peak of its distribution cycle, would eventually and suddenly be replaced by maps viewed on fixed and portable screens. I thought it likely that the "replacement" displays would be individually customized to reflect the location of the user. In addition, I suspected that the map content displayed in the future would be relevant to the user and not based on the design opinions of the "guardian cartographers" who previously had decided such matters before an individual map was printed and distributed.

D. Related history.

It had taken several years of research in human factors, optics, color theory, and computer science to begin to understand the complexity of the human perceptual mechanism. It took several more years to begin to understand how cartographers might create map displays that could be matched to the ability of the map reader to potentially enhance the speed and accuracy of map use. I gained this knowledge from reading thousands of articles. Next, I sought introductions to some of the giants in the fields of human factors, psychology, and visual search. More often than not, these industry leaders took pity on me as they found issues involving the perception and use of maps to be an interesting topic confounded by a display that was "unfathomably complex".

E. Impacts.

The future often unrolls in a manner that we do not suspect. Although I felt that I had laid the appropriate foundation for examining the salient issues involved (paper 1) and acquired a platform to begin better understanding issues in real-time display design (paper 2), I was soon lured away from the university into the commercial world of mapping. My research into human factors and map task performance ended. I had hoped that others might have pursued the research questions I had posed at AutoCarto Six. During the intervening years I have seen little practical research leading to improvement in the use of real-time color map displays.

F. Subsequent events.

During the subsequent decade (1990s), maps began to leap the barriers of printing and physical distribution systems, while becoming a niche interest in the world of video discs and CD-ROMs. Then came the intriguing map database published online by Xerox PARC. Although rudimentary, it served as proof of the concept that extremely large spatial databases might effectively be published/served online. By the first decade of the next century, online mapping had largely replaced paper products. Users could finally access maps anywhere, anytime, while using a display that was centered on and updated based on their location.

The major innovations in technology-based mapping did not come from cartographers or GIS experts alone. These changes came through working with software engineers and computer scientists who could "see" beyond the computation slowdowns and derive methods for increasing the speed, accuracy and quality of maps intended for use on the Internet. MapQuest introduced its online mapping product in the mid-1990s, followed by Microsoft and others. Later, Google turned the model upside down becoming not only a publisher of worldwide street map data, but also the major compiler of street-level, geographic information, as well as a commercial provider of GIS-like services.

In addition, the phenomenal development of mobile telephony, initially based on WAP and later marked by the successes of the iPhone and Android operating systems, allowed map use to become portable and near-frictionless. Computerization and online distribution collapsed the cost basis of maps. In today's map market users generally do not pay to use online maps, although some legal rights in and to the data are held by the copyright owners.

Next, there occurred a somewhat curious juxtaposition of technology and cultural change. First, the use of maps was transformed when the limitations imposed by printing disappeared. Pouring "sips" of maps from a large, tuned spatial database with numerous zoom levels allowed more flexibility in customizing the output display. In turn, the advantages of real-time automation and GPS, as well as other location technologies, allowed map users to focus their maps on their locations. This notion of an "egocentric" map display occurred simultaneously with the development of social networking software that allowed users to asynchronously share their lives and daily activities, including their location, with anyone who cared to know, or to meet them wherever they were to be found.

G. So what?

Unfortunately, we continue with little knowledge on how to create a color, real-time display in a manner that would improve the performance (speed and accuracy) of map tasks.

Most major providers continue to add new tools, techniques, and functionalities in hopes of meeting a user need and, in the process, attract a dedicated user community. While many of these providers change their design from time-to time, it is obvious that these changes have more to do with branding and corporate identity than with improving the human factors aspect of spatial decisions based on the use of real-time displays. Other than endless examples modifying color, figure-ground, and the conspicuousness of text, there is little innovative or unique to be found in the world of online map display design.

It is my contention that the human factors issues discussed in my two 1983 AutoCarto Six papers remain unexplored and certainly unanswered. While paper 2 describes a microcomputer mapping and display system that, today, is laughably quaint, both papers delve into display design issues that can be resolved only by melding knowledge of cartography, display design, and human factors.

I find it troubling that thirty years after AutoCarto Six, we are not closer to understanding how to create cartographic designs that make it easier for users to achieve their map-use goals.

H. Conclusion and recommendation.

In reading my 1983 contributions to AutoCarto Six, I find that they describe, in reasonable detail, a program that needs to be undertaken by some intrepid person who has knowledge of human factors, display design, and cartography. While capable human factors and knowledgeable display design practitioners are flourishing, I am not certain that a sizable pool of cartographic researchers still exists, but I hope I am wrong.

The challenge is worthy and its resolution may provide untold advantages for all map users.

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The Class of 1980s: Contributions to Local Government GIS Implementation and Management Methods

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ABSTRACT. The City of Calgary was among a group of local governments that developed automated mapping and geoprocessing capabilities to achieve GIS functionality using interactive graphics systems in the 1970s and early 1980s. They had similar goals, challenges, and approaches, as well as unique methods, and shared ideas collaboratively to help each other and the field progress. Calgary's focus was on developing multipurpose, multiparticipant automated mapping and geoprocessing facilities (the term "enterprise GIS" was not in use yet) based on high-accuracy base and parcel maps, and the 1983 AutoCarto paper discussed this approach. This paper reflects on Calgary's early experiences, its contributions to the emerging body of knowledge in local government GIS implementation and management, and some of the key concepts and practices that grew out of the collaboration among the 1980s' GIS implementation peer group.

KEYWORDS. City of Calgary, local government, computer mapping, automated cartography, GIS, geoprocessing, base maps, GIS implementation, GIS management.

A. Title of AutoCarto Six paper.

Computer mapping development at the City of Calgary.

B. Reason for paper.

The purpose of the paper was to share the City of Calgary's experience developing foundational automated mapping and geoprocessing capabilities, introducing these capabilities into departments' operations, and coordinating and managing data development and sharing.

C. Thoughts shaping the paper.

Three main concepts guided the City of Calgary's automated mapping and geoprocessing program and the paper.

The first was implementation of the multipurpose cadastre model. The model's components were a geodetic control reference framework, high accuracy base maps, a cadastral overlay, and linkage mechanisms providing access to administrative land records and systems. The City of Calgary had a rare opportunity to implement the model by creating the high-accuracy base maps it required. At the time, the linkage between the mapping system and the land records systems required the development of geoprocessing software on the mapping and mainframe systems and "sneakernet" to transfer data extracts between the two environments.

A second factor was the potential for myriad benefits of centralized, multi-user automated mapping and geoprocessing facilities. Such centralization could reduce duplication and conflict in mapping efforts, increase data sharing, and aid many city operations.

A third and key concept was the focus on the management methods required to achieve the necessary coordination among city departments.

D. Derivative attributions.

Vision for the potential of GIS and methods for developing systems were based on the foundational concepts presented by Duane Marble, Hugh Calkins, Roger Tomlinson, Ed Horwood, and Jack Dangermond.

The multipurpose cadastre concepts and procedures were developed by the National Research Council's Panel on the Multipurpose Cadastre (1980).

The advancements of GIS in Canada and their focus on developing quality base maps provided valuable concepts and approaches, as well as unique opportunities. In particular, Alberta Land Surveyor Ken Pawson introduced, championed, and realized the control survey program that served as the foundation for the creation of the accurate base map data for Calgary (Larmour 2005). The agreement between the province and the city enabled the creation of the maps.

Burt Piepgrass was the GIS visionary at the City of Calgary, striving to implement the multipurpose cadastre model and designing the parcel mapping and linkage concepts and mechanisms (Piepgrass 1980).

E. Original contributions.

The City of Calgary's automated mapping and geoprocessing project was a practical application of the multipurpose cadastre model. Other local and state governments had implemented components of the model for land records improvements and mapping capabilities; however, the publication of the model was recent and Calgary was among the first to define, design, and implement their system specifically according to the model.

The process for producing high accuracy maps was also a somewhat unique opportunity. The Province of Alberta had arrangements with the cities of Calgary and

Edmonton to produce these high accuracy maps based on an improved geodetic control network, recompilation and reconciliation of all registered survey plans using filed ties between the registered plans and the new survey control network. The province performed the computation step and the maps were produced by the cities. The City of Calgary then created the parcel overlay in exact correspondence to the survey ("legal") base maps, using property descriptions.

The city's approach and experiences with coordinating multiparticipant mapping and geoprocessing capabilities were not entirely new, but contributed to the nascent topic of GIS management best practices. The city's approach included centralized base map and parcel map production, maintenance, and management; creation of user-oriented overlays and data; decentralized user input of data; data standards; data sharing; stakeholder committees; and departmental coordination.

F. What was new and different in the paper.

Calgary's methods for developing the components of the multipurpose cadastre – geodetic control, base maps, cadastral overlay, and linkage mechanism – were described (although the model was not directly discussed in this particular paper).

Calgary was one of a few local governments which had the opportunity and resources to create high-accuracy base maps from survey sources. Calgary's base maps were created directly from geographic coordinates, rather than from digitized data, aerial photography, and other sources. The paper describes data sources and the process for constructing the base maps.

The paper also describes how the parcel overlay was constructed on the survey-based base maps using legal descriptions. This was another process that few local governments had the resources to perform.

The parcel database and the ability to link it to other city databases were similar to the approaches taken by other municipal systems, so Calgary's contributions added to the growing best practices in this area. One difference however, was that the high precision of Calgary's combined base/parcel map enabled very accurate and large scale representation of spatial data.

Calgary's multiparticipant and multipurpose automated mapping and geoprocessing goals were not new in themselves, but the city's particular management approaches for achieving them added to the experience and knowledge base in this early wave of GIS management development.

G. Impacts.

The paper generated interest and discussion about the multipurpose cadastre and its application. Other local governments also were using interactive graphics systems for automated mapping and applying similar approaches to using the systems database capabilities and establishing linkages to other systems. Documenting and discussing these approaches increased understanding and progress.

Calgary's city-wide high accuracy base and parcel mapping demonstrated its potential and value. Field measurements and other features automatically registered with the base maps. The high resolution of the base maps enabled map use, asset location, and measurement that reduced the cost of city operations and enabled new ways of depicting, managing, and using spatial data. Many local governments could not yet afford such accurate mapping, but seeing the methods used and benefits achieved by a peer, helped others plan and build their systems, as is so often the case with GIS.

Coordination of city departments and management of shared resources were necessary to achieve the goals of multipurpose, multiparticipant automated mapping and geoprocessing programs. Many local governments were developing methods for doing so, and Calgary's approach was one variation of these methods that contributed to their evolution.

Discussion among cities pursuing similar development paths – notably Edmonton, Toronto, Burnaby, Chicago, and Milwaukee – gave us an opportunity to share our experiences, challenges, ideas and solutions and this sharing enabled us all to move forward together.

H. Conclusions/Findings/Next steps.

The automated mapping and geoprocessing capabilities and benefits provided a foundation for GIS development in Calgary, but the city still had a long road ahead. In 1983 GIS was a new concept for the city. The automated mapping and geoprocessing, as available in the CADD/GIS system, were at the limit of their understanding, acceptance, and commitment, so in the mid-1980s they dismissed the option of obtaining specific GIS software. A spatial information management system development project was implemented in the early 1990s but lost momentum. In 1999 the city embarked on an enterprise GIS approach with Esri software, and continued evolution and migration of the system from there. (Eason 2000; Rasmussen and Szarmes 2001; Waters 2008). Today the city's GIS is an exemplary system.

Many local governments followed similar paths. The interactive graphics systems on which many built their automated mapping and geoprocessing systems presented challenges. GIS adopters in the 1980s and 1990s faced various challenges including the relative novelty of GIS, a lack of a body of GIS implementation experience, technical limitations, methodological challenges, organizational difficulties, underestimation of resource requirements, resource constraints, and economic downturns (Kevany 1979; Somers 1987, 1989, 1998, 2000; Tomlinson 1987). Yet they found solutions and persisted. Today the path to successful GIS implementation is somewhat more assured.

In 1983, the value of high-accuracy base maps was recognized, but not within the reach of most local governments. Over time, access to new technology and better and more affordable data sources and conversion methods enabled organizations to implement high-accuracy data and achieve the related benefits (Somers 1998b).

In the 1980s most organizations focused on the technical aspects of GIS. However, in order to implement, manage, and use the technology effectively, GIS implementers began exploring the management aspects of GIS. In particular, management issues were important to local government due to the characteristics of their GISs. Some of these key characteristics include the enterprise approach, large resource requirements, the enduring nature of programs vs. projects, the multiparticipant and multipurpose nature of the GISs, coordination among departments, and centralized management coupled with decentralized use. Local governments needed to develop GIS management solutions for these challenges.

Thus, much of the body of knowledge of GIS management best practices grew out of local government experiences (Somers 1998c, 2002). GIS management is now a recognized and prominent part of the GIS field. For example, URISA recently formed the GIS Management Institute to give the area more focused attention and development.

Still, many challenges remain in GIS management. One of these is the side effect of the local government origins of the approaches and best practices. As such, they tend to embed assumptions that are local government-centric. For example, the “ideal” of enterprise operation may not be as applicable to other types of organizations. So evolving GIS management practices must be evaluated for appropriateness for each organization and situation in which they are applied. In addition, GIS management best practices are a moving target. Technology and its use and impact on organizations, individuals, and society continue to evolve. Organizations and the roles that GIS plays within them are also evolving. So as GIS management best practices are being identified, documented, and adopted, we must be careful not to inappropriately force “old” practices on “new” situations.

Local government GIS adventures in the 1980s were collaborative and fun. Everyone was very excited about the potential. Calgary perhaps did not invent completely new ideas, but applied, combined, and extended emerging approaches and added to the growing body of knowledge by sharing its experiences. There was a strong sense of camaraderie among the group of early local government automated mapping and GIS adopters. The environment of sharing and collaboration developed many of the GIS management best practices that are now mainstays of GIS implementation and management, and such collaboration is continuing to help us move the field forward together.

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On the Transfer of Remote Sensing Classifications into Polygon Geocoded Data Bases in Canada

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ABSTRACT. In order to facilitate the updating of geocoded data bases with timely resource information, a standard format for polygon data was defined in 1979 through the efforts of the Spatial Data Transfer Committee (SDTC) (Goodenough *et al*. 1983). This format was adopted as a standard by four Canadian federal government departments, the LANDSAT Ground Station Operations Working Group (LGSOWG) and several provincial agencies in Canada (Goodenough *et al*. 1979). One of the objectives of the SDTC was to demonstrate the two-way transfer of data between the Canada Centre for Remote Sensing (CCRS) of Energy, Mines and Resources Canada and Lands Directorate of Environment Canada. Our paper in AutoCarto VI described the successful rasterization at CCRS of polygon data from Lands Directorate and explained the topological problem which prevented the generation of thematic maps from the data after being entered into the Canada Geographic Information System (CGIS) data base at Lands Directorate. The limitations of the software developed for this application were described. The successful transfer of SDTC format data from CCRS to Statistics Canada was fully described in a companion paper (Korporal, 1983). Thirty years later, movement of remote sensing data and classifications into GIS systems has become commonplace. This paper describes some of the current issues in remote sensing and GIS integration.

KEYWORDS: Remote sensing, GIS, geographic information, data interchange, big data.

A. Title of AutoCarto Six paper.

On the transfer of remote sensing classifications into polygon geocoded data bases in Canada.

B. Reason for paper.

The AutoCarto Six paper was published to show the implementation of an exchange standard for polygon data.

Several lessons learned from the implementation were fed back to both the standards writing committee and the software implementation group.

C. Thoughts shaping the design of the 1983 paper.

The 1983 paper provided a description of the requirement for sharing data between organizations. In this case it was sharing data between the Canada Centre for Remote Sensing (CCRS) at the Department of Energy, Mines and Resources, the Geocartographics Group at Statistics Canada, the Lands Directorate at Environment Canada, and the Land Resource and Research Institute at Agriculture Canada.

An *ad hoc* interdepartmental committee developed the Spatial Data Transfer Committee (SDTC) standard, and software was developed to implement the standard at CCRS. An overview of the SDTC format was presented, plus information on the implementation platform and software. Next an overview of the vector (chain) to raster format conversion was given, followed by a raster to vector conversion overview.

Descriptions of technical issues with the format, software, hardware and implementation were also provided. The conclusion indicated that there were still challenges in the implementation due to various technical issues, such as chain definition for the "figure 8 problem", and computational performance.

D. Derivative attributions.

While much work was completed in the implementation of the standard, it became clear that implementing a fully operational exchange standard was complex and required more work and resources. The end products of such a transfer needed to be accurate with no errors of omission or errors of commission allowed.

Further, since these implementations were costly to develop and required extensive QA/QC to ensure correct operation, the private sector was reluctant to take on the task of developing commercial software to support such standards.

By the early to mid-1990s it was clear that Canada could not and should not develop its own standards, but should participate with the international community to develop international standards that are or can be supported by commercial software vendors.

E. Original contributions.

This was the first attempt in Canada to develop a two-way path between a remote sensing image analysis system and a geographic information system. The two-way transfer of data was successfully demonstrated. However, the "figure 8 problem" meant that at the GIS system end, some manual edits remained.

F. Impacts.

This paper did lay the groundwork for some fundamental changes that occurred over the next decade. These included:

1. Implementing (and supporting) a large variety of interchange standards in Canada through in-house software was no longer economically viable. It was better for Canada to help develop international standards, and then use commercial versions of the software for these standards.

2. The process of developing a standard and then implementing and testing the supporting software is still used today. In fact, this is the process that standard development organizations like the Open Geospatial Consortium (OGC) currently use to develop new international standards.

G. What was new in the paper?

This was one of the first papers that described the SDTC standard, and the transfer between GIS and remote sensing image analysis systems. It was one of the first papers to describe implementation and application issues.

H. What was different in the paper?

At the time, it was not possible to automatically exchange remote sensing classifications and GIS information. The remote sensing and the GIS communities had a vision of being able to automatically update GIS information for decision making purposes, and the paper described how important it was and still is to have the most up-to-date information for the decision making.

While the vision of automatic updates is still alive today, an implementation still eludes the community due to the complexities of GIS, scale, and object representation (Daley *et al*. 1979; Hay *et al* 1997). The science and technology are closer to a working system than they were in 1983, but there is still significant research going on to help integrate GIS and remote sensing data. One approach was to use intelligent systems. The System of Experts for Intelligent Data Management (SEIDAM) was a multi-agency Canadian and NASA project that integrated remote sensing and GIS data for forest mapping with 120 expert systems (Goodenough *et al.* 1994; Goodenough *et al.* 1999).

I. Conclusions/Findings/Next steps.

The paper was a useful first step, but computer technology has improved to such an extent that many of the computer and graphics limitations that were outlined in the paper have been overcome (ESRI Canada 2011; GeoConnections 2013).

Also in the paper it mentions that 10-meter resolution satellite sensors were (at the time) high resolution. Today, sensors have improved to the point where sub-meter resolutions are commonplace.

In addition, the whole process of developing and implementing standards has changed. International organizations now develop broad-ranging geomatics standards, and this makes it economically viable for numerous commercial and open source software companies to develop software to support these interchange standards.

With hundreds of satellites in space, remote sensing is challenged by data volume, data complexity and multisensor integration over space and time. Data policies can fuel such integration for greater social benefit or block such integration for commercial advantage.

J. References.

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Goodenough, D., G. W. Plunkett, and J. J. Palimaka, 1983. On the transfer of remote sensing classifications into polygon geocoded data bases in Canada. In *Proceedings of the Sixth International Symposium on Automated Cartography.* Vol. II*:* 598-606.

Goodenough, D., D. Charlebois, S. Matwin, and M. Robson. 1994. Automating reuse of software for expert system analysis of remote sensing data. *IEEE Trans. on Geos. and Rem. Sens.,* vol. 32: 525-533.

Goodenough,D., D. Charlebois, A. S. Bhogal, A. Dyk, and M. Skala. 1999. SEIDAM: A flexible and interoperable metadata-driven system for intelligent forest monitoring. In *International Geoscience and Remote Sensing Symposium*: 1338-1341.

Hay, G., K. O. Niemann, and D. G. Goodenough. 1997, Spatial thresholds, image-objects, and upscaling: A multi-scale evaluation. *Remote Sens. Environ,* vol. 62:1-19.

Korporal, K. 1983. A demonstration transfer of remotely sensed data utilizing the standard format for the transfer of geocoded polygon data. In *Proceedings of the Sixth International Symposium on Automated Cartography.* B.Wellar, ed. Vol.II: 607-615.

Author Bio-notes

The authors of papers in *AutoCarto Six Retrospective* are a special group among the luminaries in automated cartography, GIS, and related fields. Three reasons in particular describe their eminence.

First, 30 years after publishing papers in the proceedings of the Sixth International Symposium on Automated Cartography, they are again responding positively to a request to share their expertise and experience. This is an exemplary illustration of the meaning of the phrase, “Staying the course”.

Second, with a minimum of 30 years involvement in one or more of the research, training, education, design, and practices aspects of automated cartography, GIS, and related fields, the contributors to *AutoCarto Six Retrospective* bring an exceptional degree of multi-dimensional scope and maturity to the task.

By way of brief elaboration, even the younger participants in Autocarto Six – graduate students, recently-minted professors, entry-level government researchers, fledgling entrepreneurs, etc., – are now in the later stages of their careers, and many authors and co-authors of papers in 1983 are now likely to be of the emeritus, *éminence grise*, or thoughtfully retired variety, whether from academe, government, or business.

As this document demonstrates, the *Retrospective* project has proven to be one of those rare occasions when it has been possible to assemble a cogent body of engaged expertise and experience for one more “Kick at the can”. In my experience, this assembly of talent represents an expression of extraordinary dedication and collegiality.

Third, a retrospective exercise can only be credibly undertaken by a critical mass of individuals with substantive pasts. In the case of *AutoCarto Six Retrospective,* that criterion is vastly exceeded by a group of authors who have produced a large number of related publications among their other achievements, and are widely recognized as major forces in the evolution of automated cartography, GIS, and associated fields.

There is much more that could be said about the authors, but it appears best to allow the authors themselves to have the last word.

Authors were invited to provide bio-notes and photographs for the information of current and future readers of ***AutoCarto Six Retrospective.*** I hasten to emphasize that these bio-notes barely scratch the surface when it comes to details about publications, patents, awards, etc., and I encourage readers to follow the provided links or other sources to learn more about the distinguished contributors to this book.

Barry Wellar, Editor

Bio-notes of authors are presented in alphabetical order of surnames, as follows:

Marc P. Armstrong

Marc P. Armstrong is a Professor in the Department of Geographical and Sustainability Sciences at The University of Iowa, where he has worked since 1984. During the 2013-2014 academic year, he is serving as Interim Chair of the Department of Cinema and Comparative Literature. He also holds a courtesy appointment in the Graduate Program in Applied Mathematical and Computational Sciences. Armstrong was named a College of Liberal Arts and Sciences (CLAS) Collegiate Fellow in 2005 and he served as Interim Associate Dean for Research in CLAS in 2006, as Interim Director of Iowa's School of Journalism and Mass Communication in 2007 and 2008, as Interim Director of the Division of World Languages, Literatures and Culture in 2010-11 and as Interim Chair of the Department of Communication Studies in 2011-2013. Armstrong's Ph.D. is from the University of Illinois at Urbana-Champaign. A primary focus of his research is on the use of cyberinfrastructure to improve the performance of spatial analysis methods. Other active areas of interest focus on the use of geospatial technologies by groups, and geographic aspects of privacy. Dr. Armstrong has served as North American Editor of the *International Journal of Geographical Information Science*, has served on the editorial boards of six journals and has published more than 100 academic papers, including articles in a wide variety of peer-reviewed journals such as *Annals of the Association of American Geographers*, *Photogrammetric Engineering and Remote Sensing, Geographical Analysis, Statistics and Medicine, Mathematical Geology, Computers & Geosciences, International Journal of Geographical Information Science*, *Parallel Computing*, *Computers, Environment and Urban Systems*, and *Journal of the American Society for Information Science*.

Michael Blakemore

Michael Blakemore started out as a historical geographer, with his research focusing on computerising the 1086 English Domesday Book (the equivalent of a modern census, but since it was not collected using information technology the data were available much more rapidly than the early 21st century). Being incapable of drawing maps he worked developing early versions of computer mapping packages, and from there he was diverted into more modern geographic information databases and systems.

He led the development of the UK official labour market statistics system Nomis (www.nomisweb.co.uk) from 1983 to 2000 when his interests had moved to egovernment and the wider information society.

In 2004 he looked ahead to the pensions crisis and 'retired' from the University (where he is Emeritus, and is now based in the Business School) to join a European consultancy group and work on a portfolio of wider activities that will avoid him ever having to retire and vegetate.

Assignments and interests include work with the European Commission on higher education internationalisation and reform, innovation and entrepreneurship, inclusion and disability in the information society (for UNESCO), and anything that appeals to him. (Being a Geographer allows you to be interested in everything).

If you are not bored already, go to his Linkedin profile at:
http://uk.linkedin.com/pub/michael-blakemore/38/250/376.

Barbara P. Buttenfield

Barbara P. Buttenfield is Professor of Geography at the University of Colorado in Boulder. She is Director of the Meridian Lab, a small research facility emphasizing visualization and modeling of geographic information and technology. She is also a Research Faculty Affiliate with USGS Center for Excellence in GIScience. Her research focuses on map generalization, multi-scale geospatial database design, cartographic visualization and information design. She has published on spatial data infrastructures, adoption of geospatial technologies, and digital libraries.

She is a Past President of the Cartography and Geographic Information Society (CaGIS), and a Fellow of the American Congress on Surveying and Mapping (ACSM).

In 2001, she was named GIS Educator of the Year by the University Consortium for Geographic Information Science (UCGIS), in the inaugural year of the award. She was elected a Fellow of UCGIS in May 2013. She served six years on the National Research Council's Mapping Science Committee, and is serving currently on the U.S. Census Bureau's Scientific Advisory Committee.

Details about her research projects can be found at:

http://www.colorado.edu/geography/babs/webpage/ and
http://greenwich.colorado.edu/nsf/nsf.html.

Bernard F. Campbell

Following 25 years with Tourism Canada, latterly as Director General of Development, Campbell was named Deputy Minister, Alberta Department of Tourism in 1987.

In 1993 he left the Alberta Government and with partners Kent Stewart, Anna Pollock, and Mary Wilson, he became a Principal with The Strategy Group.

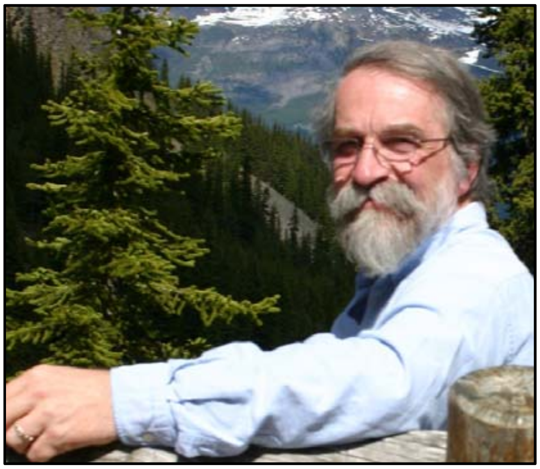
In 1996 Campbell and Wilson, Senior Partners in Westwinds Tourism Consultants, joined the World Travel and Tourism Council in London, England as Senior Policy Advisors.

Campbell has undertaken international strategic tourism development projects in Ukraine and the Philippines, and with Wilson in Jordon and Lithuania.

Campbell has lectured at the Univsidad Externado in Bogota, Columbia, the MBA programme at the University of Alberta, and at Simon Fraser University.

Campbell returned to Canada in 2009 and is now retired, living in Victoria, B.C.

Nicholas Chrisman



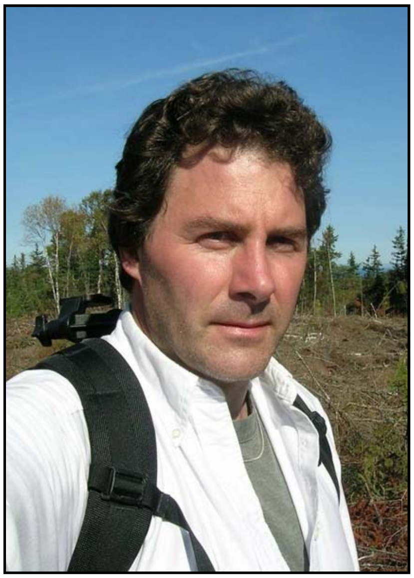
At the time of AUTO-CARTO 6, Nicholas Chrisman was Assistant Professor at University of Wisconsin-Madison, with a one-year old PhD obtained in Bristol UK. He had moved into the classic academic track after ten years at Harvard Lab for Computer Graphics. Following 5 years at Madison working on implementation of GIS, he moved on to University of Washington (17 years), then 8 years as Scientific Director of the GEOIDE Network, based at Université Laval in Quebec City, QC. For the past year he has been Professor at RMIT University in Melbourne, Australia.

Throughout this peripatetic career, he retains an interest in time and history as it applies to geographic information.

http://www.rmit.edu.au/staff/nicholas-chrisman

http://esripress.esri.com/display/index.cfm?fuseaction=display&websiteID=82

David Colville



In 1983 David graduated from the Scientific Computer Programming Diploma program offered by the Nova Scotia Land Survey Institute, which is now known as the Centre of Geographic Sciences (COGS) at the Nova Scotia Community College (NSCC). David also holds a BSc in Biology from Acadia University and an MES from Dalhousie University. He has over 25 years' experience teaching GIS; for eight of these years he held a dual Department Head / Faculty position and for 13 years he held a dual Research Scientist / Faculty position.

Today, David is a Research Scientist with the Applied Geomatics Research Group (AGRG) which is affiliated with COGS. He is an active co-supervisor in the MSc Applied Geomatics program (a Joint Masters program offered by Acadia University and the NSCC), and has held adjunct positions with Acadia, Dalhousie, and the Agricultural College. David is the principal investigator on a number of *in-situ* sensing and meteorological monitoring studies in southwestern Nova Scotia. His landscape ecology interests lead him to landscape-level studies involving LiDAR-based topography and vegetation analyses for agriculture, wildlife habitat, and forest change applications.

Ian K Crain

Dr Crain holds BSc and MSc degrees from McGill University in Geophysics, and a PhD from Australian National University on the topic of global tectonics. As a scientist with the Geological Survey of Canada, and the (then) Energy Mines and Resources Computer Centre, he did pioneering work on automated contouring, and the mapping of airborne geophysical data. In 1973 he was among the first group of research scientists hired by the fledgling Canada Centre for Remote Sensing, where he did research on pattern recognition and information extraction from satellite imagery. At the time of AutoCarto-VI he was Director of the Canada Land Data Systems (CLDS) Division of Environment Canada, responsible for the operation, as well as the overhaul and modernization of the Canada Geographic Information System (CGIS). It was during this period that the original IBM-designed drum scanner was donated to the Canadian Science and Technology Museum and was replaced by a modern laser-based scanner driven by a mini-computer, the first end-to-end digital map products were produced, and on-line interactive access to CGIS data commenced.

In 1986 he was seconded to the United Nations Environment Programme in Nairobi Kenya to establish the Global Resource Information Database (GRID) project which used GIS and remote sensing to integrate global environmental data.

In late 1988 Dr. Crain moved to the Alberta Government to establish their province-wide Land Resources Information System (LRIS), and subsequently became an Associate Professor of Spatial Information Systems in the Geomatics Engineering Department of the University of Calgary where he taught and did research on advanced Spatial Information Systems. Since 1992 he has been a Principal of his own company, The Orbis Institute, providing consulting and capacity building in environmental and resource information systems, mainly in support of international development projects for CIDA, development banks, UN agencies, and NGOs. In this capacity he was for over a decade the Senior Advisor to the UN World Conservation Monitoring Centre in Cambridge England, and similarly developed the information management policies for the North American Commission for Environmental Cooperation.

Jack Dangermond

Jack Dangermond is the President of Esri, which he and his wife Laura founded in 1969, in Redlands, California. Esri is now the largest GIS software company in the world with more than a million users in some 300,000 organizations in 200 countries.

In recognition of his contributions to GIS technology he has received fourteen honorary degrees, and seventeen national and international awards and medals. Besides actively directing and managing Esri he serves on numerous national and international advisory committees and boards. He has contributed extensively to the literature of GIS and related fields and is a frequent speaker at international conferences.

Michael Dobson

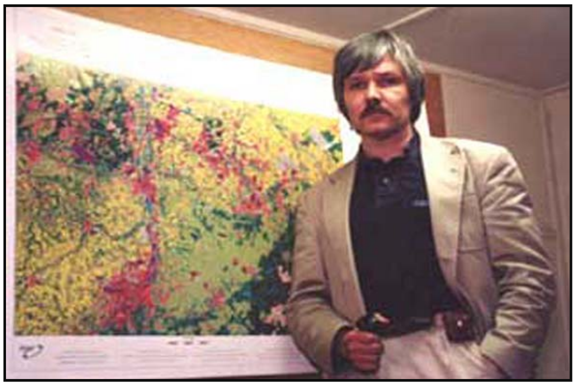
Michael Dobson has over thirty years of senior management experience focused on the uses of geographic information. Through his blog, *Exploring Local* (http://blog.telemapics.com), he is known for delivering unique insights into the dynamics of the markets involving spatial information, such as GIS, mapping and navigation.

As president and principal consultant for TeleMapics (www.telemapics.com), Dr. Dobson provides strategic technical consulting focused on the markets for geographic information, especially mapping, GIS, location-based services, and local search. Other specializations offered include product/services design, product/services development planning, and operations management of the product development cycle.

He was previously employed as the CTO and executive vice president of technology for go2 Systems where he served as the corporate officer responsible for technology, engineering, IT, and product development. go 2 supplied yellow page/local search services, including routing, under stringent service level agreements to MSN Wireless, AT&T Wireless, Sprint, Nextel, Verizon and other major wireless carriers. Previously, Dr. Dobson was the chief technologist for Rand McNally where he managed the technology and software development organizations supporting the company's commercial and consumer products and services. He also served as the company's vice president of business development, chief cartographer and public relations spokesperson. Dr. Dobson's initial job in geography was with the State University of New York in Albany where he was an assistant and then associate professor of Geography.

Dr. Dobson's contributions to his profession include numerous refereed articles, opinion columns in popular publications, national and international television pieces, invited presentations and membership on the Mapping Sciences Committee of the National Research Council of the National Academy of Science of the United States. In 2012 his profile was one of the top 10% most viewed on LinkedIn, and his SlideShare presentation (www.slideshare.net/mdob/dobson-presentation-nys-geo-summit-for-slideshare) from the New York State GeoSummit was viewed over 10,000 times.

Jean-Paul Donnay



Professeur Ordinaire à la Faculté des Sciences de l'Université de Liège ; fondateur du laboratoire SURFACES et de l'Unité de Géomatique de l'Université de Liège, titulaire de la chaire de Cartographie et Systèmes d'information géographique.

Docteur en sciences (1985), Master en sciences appliquées (1983). Candidatures, licences (~ Bach & Master, ancien régime) et agrégation en sciences géographiques (1976).

190 publications, dont une dizaine d'ouvrages (http://orbi.ulg.ac.be/).

Extrait du C.V. :

- Membre effectif du Comité national de géographie de la classe des sciences de l'Académie royale de Belgique ; du Comité belge de cartographie et systèmes d'information géographique (pro-président 1995-2003) et de la Commission de l'Atlas national de Belgique.
- Fondation J.A. SPORCK : président.
- AM/FM-GIS Belgium-Luxembourg : co-fondateur.
- Association of Geographic Information Laboratories in Europe (AGILE) : membre fondateur.
- GISDATA, European Science Foundation : délégué belge au comité directeur (1991-1997).
- Professeur invité des universités de Louvain-la-Neuve (1989-1993) et de Montpellier (2005).

Informations complémentaires sur les sites :
http://www.geomatique-liege.be/cvjp/Pages/CVJP_Accueil.htm
http://www.geo.ulg.ac.be/

W Randolph Franklin

W Randolph Franklin is a Professor of Electrical, Computer, and Systems Engineering, with a courtesy joint appointment in Computer Science, at Rensselaer Polytechnic Institute RPI), Troy, NY, USA. His degrees include a B.Sc. from Toronto and A.M. and Ph.D. in Applied Mathematics from Harvard.

During 2000-2002 Franklin served a rotation to the National Science Foundation, as Director of the Numeric, Symbolic, and Geometric Computation Program. Franklin has also held visiting positions in the Electrical Engineering and Computer Science Dept at the University of California at Berkeley (as Visiting Professor), the US Army Topographic Engineering Center, Ft Belvoir, the Dipartimento di Informatica e Scienze dell'Informazione, Università degli Studi di Genova, Italy, the Dept. de Science Géodésique, Université Laval, Quebec City, Canada, the Division of Information Technology, Commonwealth Scientific and Industrial Research Organization, Canberra, Australia, and the Institute of Systems Science, National University of Singapore. He also helped found two (now-defunct) hi-tech startups, Hudson Data Systems, and Attic Graphics, Inc.

His research hobby is designing and implementing small, simple, and fast data structures and algorithms for large geometric datasets. Note that efficiency in both space and time can become more important as machines get faster. This research is applicable to computational cartography, computer graphics, computational geometry, and geographic information science. His long term unsolved problem is to understand the mathematics of terrain. Field work to understand terrain has included climbing Mt Kilimanjaro, walking the Haute Route from Chamonix to Zermatt, and kayaking and hiking in the rainforest north of Manaus Brazil.

Franklin's awards include an NSF Presidential Young Investigator award and an RPI Early Career Award. He has graduated 16 doctoral and 68 masters students.

For more information, see http://wrfranklin.org/.

Herbert Freeman

Herbert Freeman received his B.S.E.E. degree from Union College, Schenectady, NY (1946) and his Masters (1948) and Dr.Eng.Sc. degrees from Columbia University (1956). From 1948 through 1960 he was employed by the Sperry Corporation, where he designed the company's first digital computer, the SPEEDAC, which was completed in 1953. In 1960 he joined the faculty of the Electrical Engineering Department at New York University, becoming chairman of the department in 1968.

From 1975 through 1985, he was professor and director of the Image Processing Laboratory in the Electrical, Computer and Systems Engineering department at Rensselaer Polytechnic Institute, in Troy, NY, and in 1985 he joined Rutgers University in Piscataway, NJ as State of New Jersey Professor of Computer Engineering and Director of the Center for Computer Aids for Industrial Productivity, a university-industry-government collaborative research center. Among some of his technical contributions are the invention of the *chain code* for line-drawing representation (commonly known as the "Freeman chain code"), the concept of *characteristic views* in machine vision, and the development of high-quality automated cartographic text placement technology.

He is a past Chairman of the IEEE Computer Society's Technical Committee on Pattern Analysis and Machine Intelligence, a founding member and past President of the International Association for Pattern Recognition (IAPR), and served as program chairman of the 1974 World Computer Congress in Stockholm, Sweden. He is a Life Fellow of the IEEE, a past NSF Post-Doctoral Fellow, a Guggenheim Fellow, a Fellow of IAPR, and a Fellow of the ACM. In 1994, the International Association for Pattern Recognition awarded him its K.S. Fu prize "for his pioneering contributions to the representation and analysis of line drawing data," and in 1996, the University of Pavia, Italy, honored him with its Medaglia Teresiana for his contributions to the field of pattern recognition.

He has held visiting positions at M.I T., The Swiss Federal Institute of Technology, the University of Pisa, Stanford University, and the Technion, Israel Institute of Technology. He is the author or editor of seven books and has published more than 130 articles in the technical literature. In 1997 he founded a company, MapText, Inc., in Plainsboro, NJ, devoted to the automated labeling of map features. The company was sold in 2005 to Lufthansa Systems and he has been in retirement since that time.

Randy Gimblett

Randy Gimblett is a Professor in the School of Natural Resources and the Environment, Institute of the Environment, Department of Landscape Architecture and Arid Lands Studies program at the University of Arizona. He has engaged in research work studying human-landscape interactions and their associated conflicts, and public policies related to protection of special environments and environmental experiences for nearly three decades. He has published over 120 refereed papers in the field of human behavior, recreation planning and management and ecological modeling of complex adaptive systems, and specialized in building models that couple human-landscape systems across space and time at multiple scales. This work has culminated in two books published in 2002 *Integrating GIS and Agent Based Modeling Techniques for Understanding Social and Ecological Processes* by the Oxford University Press and in 2008 *Monitoring, Simulation and Management of Visitor Landscapes by* the University of Arizona Press and another in press entitled *Sustainable Wildlands: A Prince William Sound Case Study of Science-based Strategies for Managing Human Use,* by the University of Arizona Press (2011). Much of this research and applications have focused on the development of field based methods for collecting dispersed human use data coupled with agent-based modeling and its application to solve spatial dynamic problems.

David G. Goodenough

Adjunct Professor of Computer Science at the University of Victoria where he has graduate students and is a NSERC recipient. He is also an Emeritus Senior Research Scientist at Pacific Forestry Centre in Victoria, BC, of the Canadian Forest Service, Natural Resources Canada. He is a Fellow of the IEEE (1997). He was President of the IEEE Geoscience and Remote Sensing Society (1992-1993) and served as Past-President (1994-1996). Dr. Goodenough holds the following degrees: Ph.D. and M.Sc. (University of Toronto), and B.Sc. (University of British Columbia). Dr. Goodenough worked at the Canada Centre for Remote Sensing (1973-1991), where he was a Chief Research Scientist and Head of the Knowledge-Based Methods and Systems Section. He has published extensively (>260 papers). He has received the following awards: Government of Canada's Award of Excellence; the IEEE GRS-S Distinguished Achievement Award; the Canadian Remote Sensing Society's Gold Medal Award; the IEEE GRS-S Outstanding Service Award; a Natural Resources Canada Departmental Merit Award; an Energy, Mines and Resources Merit Award; and NASA Group Achievement Awards. Dr. Goodenough is Principal Investigator for the JAXA Advanced Land Observing Satellite-2, a Co-I for an NRCan/CSA Multisource Biomass Project, and an advisor for the EU project North State. He was a PI for a Radarsat-2 Forest Applications Project, a Hyperspectral Forest Applications Project, and a Co-I of a Scientific GRID Computing and Data Project for producing Above-Ground Forest Carbon Maps. Dr. Goodenough was Principal Investigator (PI) of the NASA project, Evaluation and Validation of EO-1 for Sustainable Development (EVEOSD) of forests. He was also PI of a CHRIS project, EVC, with the European Space Agency. Dr. Goodenough was the PI of the System of Experts for Intelligent Data Management (SEIDAM) Project with NASA. Dr. Goodenough's current research interests focus on methods and algorithms for forest information from hyperspectral and polarimetric radar systems in order to create geospatial products for forest species, forest health, and forest carbon. He has provided consultation on remote sensing methods and systems for civilian and defence applications. Additional information can be found at http://rseng.cs.uvic.ca/faculty/d_goodenough.html

Jean-Philippe Grelot

Jean-Philippe Grelot is a graduated engineer (M.Sc.) from École Polytechnique, France and a graduated engineer (M.Sc.) from the French National College for Geographical Sciences (École nationale des sciences géographiques).

The first part of his career was devoted to cartography within the Institut géographique national, the French National Mapping Agency, now called Institut national de l'information géographique et forestière (National Institute of Geographic and Forest Information, IGN). He developed automated production lines and served as head of cartographic units from 1979 to 1986, and head of the printing division from 1986 to 1988. He was sales and marketing director from 1988 to 2000.

During this period he was also a teacher in applied mathematics, and in cartography, at the National College for Geographical Sciences and other organizations in France and abroad.

From 2000 to 2010 he served in an office of the French Prime Minister, and was in charge of defense, national security, and crises management.

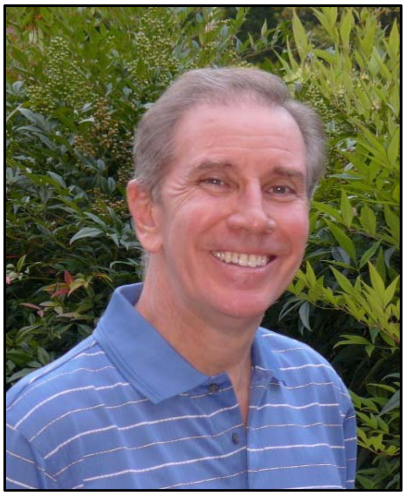
In 2010, Jean-Philippe Grelot was appointed deputy director general of IGN and chair of IGN France International, a sub-company of IGN in charge of international activities.

He is a member of the management board of EuroGeographics, the European association of national mapping and cadaster agencies, and a member of the board of the French Navy Hydrographic and Oceanographic Service.

Jean-Philippe Grelot served in the Executive committee of the International Cartographic Association as vice president from 1987 to 1991, and as secretary general and treasurer from 1991 to 1999. He was vice president of the French Cartographic Committee from 1988 to 2002.

In 1999 he was awarded Honorary Fellowship of the International Cartographic Association, and in 2010 Honorary Fellowship of the Hellenic Cartographic Society.

Stephen C. Guptill



Stephen Guptill is an independent consultant specializing in geographical information science and currently resides in Oakton, Virginia. Guptill retired from the U.S. Geological Survey in 2007 and during his 32 year career at USGS he was internationally recognized for his contributions to the field. Before retiring he founded and directed the USGS Center of Excellence for Geospatial Information Science. He also conducted spatial analysis research with colleagues from the Centers for Disease Control and Prevention to determine the environmental influences on emerging zoonotic and vector borne diseases.

Guptill received a Ph.D. (1975) and M.A. (1974) in Geography from the University of Michigan, Ann Arbor, Michigan, and a B.A. (1972) in Chemistry and Geography from Bucknell University, Lewisburg, Pennsylvania.

From 1991-1999 Guptill served as executive secretary of the International Cartographic Association Commission on Spatial Data Quality. He was president of the American Cartographic Association, ACSM in 1994. From 1990-1992 he served as the North American Editor of *IJGIS*. He chaired the Standards Working Group, Federal Geographic Data Committee from 1991-1994, and led the development of the FGDC Content Standards for Digital Geospatial Metadata. In addition, he served as the Department of Interior member on the National Science and Technology Council Subcommittee on Health and the Environment.

Guptill received the Department of Interior Meritorious Service Award in 1993. He is a Fellow of the American Congress on Surveying and Mapping, and a Fellow of the Cartography and Geographic Information Society.

Guptill is co-author of *Elements of Cartography*, 6th Edition, and co-editor/author of *Elements of Spatial Data Quality*. He has written over 80 articles and papers appearing in the natural science and public health literature.

Email: sguptill@guptillgeoscience.com

Dierk Hobbie

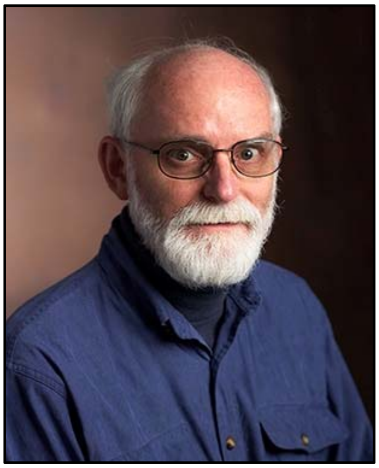
Former General Manager, Surveying and Photogrammetry Division, Carl Zeiss AG, from 1968 to 1991 various management positions in R&D Photogrammetry at Zeiss, project manager and spin doctor of orthophoto and analytical systems.

1967 Diploma in surveying from Hannover University, 1973 Doctorate in engineering science at the University of Stuttgart (while already working at Zeiss), 1998 Honorary Professor at Hannover University, having lectured there since 1989.

More than 50 publications in the fields of photogrammetry, university education of engineers, history and family research (www.hobbie.de), quite recently:

The development of photogrammetric instruments and methods at Carl Zeiss in Oberkochen (ISBN 978-3-7696-9674-5, 2010, http://dgk.badw.de/index.php?id=14 for free download) and *Separation and reunification of the geodetic and photogrammetric instrument divisions at Carl Zeiss* (in German, avn - Allgemeine Vermessungs-Nachrichten, 06/2012, ISSN 0002-5968, www.wichmann-verlag.de).

Lewis D. Hopkins

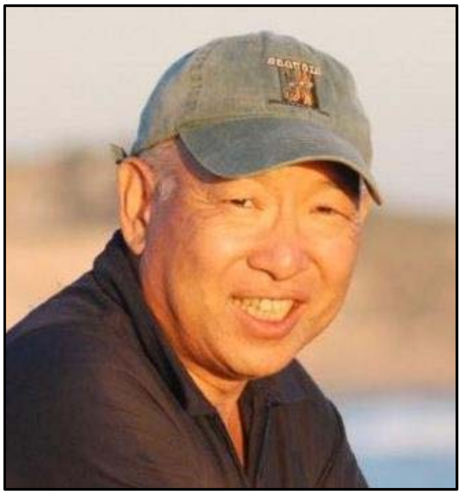


Professor Emeritus, University of Illinois at Urbana-Champaign: first in Landscape Architecture, then Head of Urban and Regional Planning. Editor (with Gill Chin Lim), of *Journal of Planning Education and Research,* 1987-1991; chair, Planning Accreditation Board. Fulbright Senior Lecturer/Researcher Nepal. Association of Collegiate Schools of Planning Distinguished Educator Award, 2007.

B.A., MRP, PhD, University of Pennsylvania. Worked with Ian McHarg and Bruce MacDougall as student and early consulting on geographic information systems; Britton Harris as dissertation advisor, yielding a continuing interest in planning theory and modeling.

Contributions cluster around two ideas: 1) Analytical planning tools should be designed to be effective in combination with capabilities of planners who use them. 2) Plans should be seen as occurring within complex multi-organizational systems rather than as controlling a system from the outside. These ideas developed in two books: *Urban Development: The Logic of Making Plans,* Island Press, 2001 and (co-edited with Marisa Zapata) *Engaging the Future: Forecasts, Scenarios, Plans, and Projects*, Lincoln Institute of Land Policy, 2007. *http://www.urban.uiuc.edu/faculty/hopkins/*

Bob Itami



Bob Itami is Director of GeoDimensions Pty Ltd in Victoria, Australia. He has a history of teaching and research at the University of Guelph, University of Arizona and University of Melbourne. His research during his academic career focused on GIS modeling, environmental simulation and decision support systems for resource management. His long term collaboration with Professor Randy Gimblett has focused on the world's first visitor simulation model RBSim. RBSim has evolved from a research project into a powerful consulting tool ideal for analyzing complex behavior of people, vehicles and vessels in land and water based recreation areas.

Since 2001 Bob has been a full time consultant focusing on recreation management, decision support systems and stakeholder engagement.

www.geodimensions.com.au

Robert Jeansoulin

Dr. Robert Jeansoulin is CNRS senior scientist in computer science, now serving as science attaché at the Consulat Général de France au Québec, after 4 years at the Embassy of France in the USA where he was in charge of new technologies for information, communications and security. Prior to his USA appointment, he taught databases at the university of Paris-Est Marne-la-Vallée (2006-2008).

He started serving as CNRS junior in Toulouse, under CNES grant (space imagery, 1978). he was visiting scientist at USC Medical Imaging Science Group (Los Angeles 1980) under a NATO grant, then at INRIA, then Professor at Université d'Orsay. Back at CNRS in 1990 (Robotics Lab., UPMC), he was co-founder of the first French research network in geomatics (http://www-cassini.univ-mrs.fr/).

He was advisor for the CNRS, fostering use of databases and math in the laboratories of the Social Sciences and Humanities Department.

From 1998 to 2004, he led the European project REVIGIS (FP4 ESPRIT, FP5 FET-IST) (http://igm.univ-mlv.fr/~jeansoul/REVIGIS/) as coordinator and principal investigator, and was Associate Professor at U. Laval (Québec, 2001-2010).

His research field is in artificial intelligence (AI) with a focus on uncertainty, as it applies to reasoning with space and time information, mostly in geomatics, and always working across disciplinary barriers. B.Sc. in Mathematics (U. Provence, Marseille 1970); M.Sc. in Computer Science (UPS, Toulouse 1974); Engineer degree (ENSEEIHT Polytech Toulouse 1976); PhD in Image Processing at university Paul Sabatier Toulouse 1981.

He has published 5 books, 20 journal articles, 80 peer-reviewed papers, and received 3 awards (IGN, Intergraph, ASPRS), in image processing and AI. He has supervised 22 PhD candidates who are now researchers, professors or engineers, mostly in labs in France, Canada, Ireland, or Tunisia. He served as witness or expert in program evaluation committees in France, Switzerland, Canada, and for the EU.

Chris Kissling

Dr Kissling was the Foundation Professor of Transport Studies at Lincoln University. He guided the introduction of the first undergraduate degree in New Zealand specializing in Transport and Logistics–the BCom (T&L), as well as Lincoln's Masters programs in Applied Science, MApplSc (Tpt Stud) and Professional Studies MProfStud (TptMgt), the latter studied part time at a distance by professionals in the transport sector in New Zealand. Over a period of four years he has also helped produce academic course materials for the Bachelor of International Logistics Management (BILM) in the Kingdom of Bahrain, offered by Bahrain Polytechnic.

Since his Doctorate in Geography at McGill University, Montreal, Canada in 1966, he has held academic positions at the University of Canterbury, University of British Columbia, Australian National University (ANU), and Lincoln University. He has worked for the OECD in Paris, and spent other sabbatical time at Northwestern University, Illinois, USA, and The London School of Economics. He has consulted to UNESCAP, ICAO, APEC Transportation Working Group, New Zealand Pacific Economic Cooperation Council (NZPECC), and various governments such as Sarawak (Malaysia), Fiji, Samoa and for Local and central Government in New Zealand. He held the position of Director of Planning Services for the Canterbury United Council prior to Local Government reorganization in 1989 whilst on special leave from ANU. Until 2013 he was the New Zealand Board member for 14 years for the Eastern Asia Society for Transportation Studies (EASTS). He is a past Chairman of the Council for the Chartered Institute of Logistics and Transport (NZ Division), and is a CILT Fellow (FCILT) and Fellow of the Royal Aeronautical Society (FRAeS).

In 2007 Kogan Page Ltd (London and Philadelphia) published a book he co-authored with John Tiffin (Professor Emeritus, Victoria University Wellington) titled *Transport Communications: Understanding Global Networks Enabling Transport Services*. This book opened a new field of study. Several doctoral students have applied concepts derived from this book in their own research. During 2014, John Tiffin and Chris Kissling expect to produce an updated e-book version of *Transport Communications.*

Following his retirement from Lincoln University at the end of 2009, he has continued research and consultant work for clients in New Zealand and in other countries in the field of multimodal transport systems planning and analysis. Sometime in 2014 the last of his Doctoral students will have completed his dissertation at which point retirement might become more of a reality but involvement in community affairs and appearance as an expert witness in court cases eliminates idle time.

Nina S. N. Lam

Professor & Abraham Distinguished Professor of Louisiana Environmental Studies in the Department of Environmental Sciences at Louisiana State University (LSU); also an Adjunct Professor with LSU Department of Geography and Anthropology and LSU Department of Oceanography and Coastal Sciences; was Chair of the LSU Department of Environmental Sciences (2007-2010), Program Director of the Geography and Spatial Sciences Program at the National Science Foundation (1999-2001), and President of University Consortium on Geographic Information Science (UCGIS) in 2004. Awards received include: the Andrew McNally Best Paper Award for an article on spatial interpolation methods in 1983; Outstanding Contributions in Remote Sensing Award from the Association of American Geographers Remote Sensing Specialty Group in 2004; LSU Distinguished Faculty Award in 2006; LSU Rainmaker Award in 2008; LSU Distinguished Research Master in 2010; and LSU School of the Coast and Environment Outstanding Faculty Research Award in 2011. Research and teaching interests are in GIS, remote sensing, spatial analysis, environmental health, and resilience and sustainability. Coedited the book *Fractals in Geography* in 1993 and authored over 70 refereed articles; served as the principal investigator or co-principal investigator of over 35 national grants; and as the advisor of two post-doctoral research associates, 16 PhDs, and 26 M.S. students.

Giulio Maffini

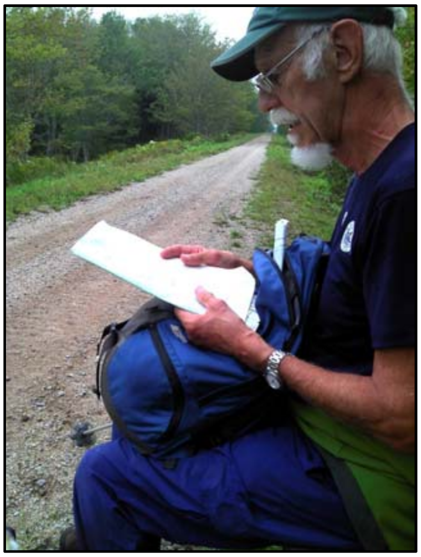
Giulio Maffini has over 40 years of experience as an entrepreneur, technology leader, and consultant. He is a passionate advocate of innovation in the design of products and services. Giulio has a track record of forming strong teams and alliances. He has built award-winning start-ups and created profitable business units inside large companies. Through a+i2 Inc., his consulting practice, he now advises companies and governments on innovation, partnering, and enterprise projects.

Prior to a+i2 Inc., (1993-1999) Giulio was Vice President and co-founder of the MCI Systemhouse, VISION* Solutions unit. Giulio worked within Autodesk for two years till 2001 to assist with the transition of the VISION* Solutions unit which was purchased by Autodesk in 1999.

From 1984 - 1993 Giulio was co-founder of Tydac Technologies, a leading Canadian GIS company. TYDAC grew out of the DPA Group, a national planning, economics, and management consulting practice with which Giulio was Vice President. TYDAC developed SPANS, the software used to analyze and model spatial data. In 1989 the company received the Canada Award for Excellence in Innovation.

Giulio was a member of the Mapping Sciences Committee, U. S. National Research Council, during the development of the National Spatial Data Infrastructure (NSDI) policy strategies, he is a member and former board member of the Geomatics Industry Association of Canada (GIAC), and currently serves on the Board of Trustees for the High Performance Computing Virtual Lab (HPCVL), an R and D consortium of Queen's, Ottawa, and Carleton universities, and the Royal Military College in Kingston.

Bob Maher



Dr. Bob Maher received his doctorate in Geography from the University of Western Ontario. His first teaching position was in the Department of Geography, Memorial University of Newfoundland. After stints in Ottawa and Edmonton, he joined the faculty at the Nova Scotia Land Survey Institute. This became the College of Geographic Sciences in 1986. He completed GIS consulting assignments in Indonesia, before heading to Esri, Redlands California. Back in Canada, he was responsible for GIS training with the Ontario Ministry of Natural Resources.

In 2000, Bob became Senior Research Scientist with the Applied Geomatics Research Group, Nova Scotia Community College in Middleton. After his retirement, he remains a resident of the Annapolis valley.

Harold Moellering

Professor Emeritus of Geography and Geodetic Science at Ohio State University, where he was the Director of the Department's Numerical Cartography Laboratory. He is past Chairman of the ACSM Committee on Automation in Cartography and Surveying and has served as a member of the Committee on Cartography of the U.S. National Academy of Sciences/National Research Council. He has served as a member of the Editorial Boards of *Cartography and Geographic Information Science,* and *International Journal of Geographic Information Systems*.

The Spatial Data Display Project was founded by Prof. Moellering in 1986 as part of the OSU NASA Center for the Commercialization of Space. The fundamental goal of this project is to develop new and enhanced approaches to cartographic visualization in two and three spatial dimensions. The project extended a simplified approach to bivariate statistical surface shading, developed an entropy model for analytical surface shading, worked with 3-D stereoscopic visualization of cartographic surfaces, and invented the MKS-ASPECT™ process for color surface rendering. This MKS-ASPECT™ development has two patents issued for this color surface rendering process.

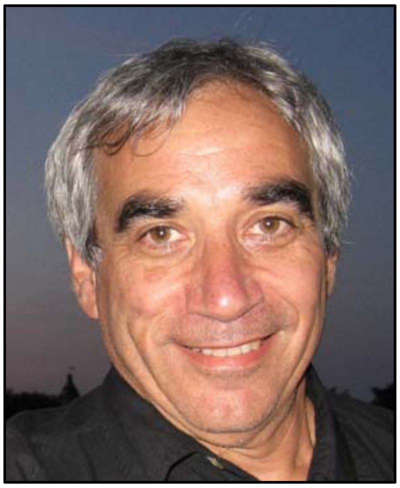
Prof. Moellering is founder and past Chairman of the U.S. National Committee for Digital Cartographic Data Standards in cooperation with the American Congress on Surveying and Mapping, the U.S. Geological Survey and the U.S. National Institute for Standards and Technology. This committee developed the scientific heart of the Spatial Data Transfer Standard (SDTS) which is Federal Information Processing Standard (FIPS) 173. For his leadership and direction of the National Committee he was presented in 1988 with the John Wesley Powell Award for Citizen's Achievement by the U.S. Geological Survey and the Ameritech Prize for Excellence in Communications. The Committees were also awarded the Australian Institute of Cartographers/BHP Engineering award for Technology Research and Development in 1988. In 1989 the standard was chosen for the Andrew McNally award for the ACSM publication "which does the most to promote the theory and practice of cartography".

Gordon Plunkett

Gordon Plunkett has a Master's Degree in Electrical Engineering, and has more than 35 years of experience in remote sensing and GIS in both the public and private sectors. He currently sits as a member of the Open Geospatial Consortium (OGC) Technical Committee, the Canadian General Standards Board (CGSB) Committee on Geomatics, the GeoBase Steering Committee, the Canadian Community Map Initiative, and the Carleton University Geomatics and Cartographic Research Centre Advisory Board. He previously sat on the GEOIDE Research Management Committee and numerous government committees. He is a member of the PEO, CIG, URISA and CRSS.

During his career, Mr. Plunkett has worked on projects in over 20 countries and has contributed to numerous scientific conferences and publications. He is currently the Director, Spatial Data Infrastructure at Esri Canada, where he is responsible for developing and supporting the company's SDI vision and initiatives, including the production of the Esri Canada *SDI Newsletter*.

Steve Prashker



Steve received his Master of Science degree from McGill University. Since 1978, he has been a member of the Department of Geography & Environmental Studies at Carleton University in Ottawa, Canada, providing computing hardware/software support for the department in his capacity as Manager of the Geomatics Laboratories.

He is also the instructor of the fourth year course Seminar in Cartography, and coordinator of the Geography, Geomatics and Environmental Studies Practicum Program.

Steve's interests include GIS applications, digital cartography, algorithm development and animation, computer graphics in general and experiential learning. He previously developed the MIGS(c) micro based mapping system, the ZAPPER(c) Toolset for cartographic line simplification, several data conversion utilities, the GeoAnimations(c) set of GIS algorithm animations, and the Anti-aliasing raster perimeter algorithm.
Steve received the University's Professional Achievement Award in 2009.

Carl Reed

Dr. Carl Reed is the Chief Technology Officer at the Open Geospatial Consortium. Dr. Reed also manages the process by which formal OGC Standards are developed and adopted by the OGC membership. Before joining the OGC, Dr. Reed was vice president of geospatial marketing at Intergraph Corporation. Reed joined Intergraph in April 1998 after a long tenure at Genasys II, where he had served as chief technology officer for Genasys II worldwide.

Early in his career, in 1977 and 1978 Reed designed and implemented the first fully interactive vector-based GIS, the Map Overlay and Statistical System (MOSS). In 1985 and 1986, Dr. Reed was the lead engineer and a software developer in the design and development of GenaMap, the world's first interactive UNIX-based commercial GIS.

Dr. Reed received his PhD in Geography, specializing in GIS technology, from the State University of New York at Buffalo in 1978. In recognition of his contributions, in 2009 Dr. Reed was inducted into the URISA GIS Hall of Fame.

David Rhind

After gaining a PhD in fluvioglacial geomorphology and post-doctoral work on geological databases, David Rhind joined the pioneering Experimental Cartography Unit. After four years there he was a member of staff in Durham University, and Birkbeck College, University of London, teaching and building a major environmental GIS system for the European Union, and Population Census mapping and analytical tools.

Subsequently he was Director General of Ordnance Survey, then President of City University London. In addition, he was a Non-Executive Director of the Bank of England during the financial crisis, and has been chairman of a major hospital trust.

At present he is chairman of the Nuffield Foundation, chairman of UK Government's Advisory Panel on Public Sector Information, and Deputy Chairman of the UK Statistics Authority (with responsibility for promoting and safeguarding the production and publication of all official statistics across the UK).

Along the way, he has published widely on GIS and other matters, notably the *GIS and Science* textbook with Professors Goodchild, Longley and Maguire. Rhind is a Fellow of the Royal Society, Britain's national academy of science.

Mark C. Shelberg

Senior Systems Engineer at Compass, Inc. Retired from the National Geospatial-Intelligence Agency (NGA) after more than 33 years of federal service. At NGA, held numerous positions such as chief of the strategic planning and performance management office, cartographic advisor to the mapping/imagery offices of the governments of Afghanistan and Iraq, chief of the cartographic techniques office, and participated and led several transformational related activities at NGA. Currently, as a systems engineer, supporting a client to develop and improve their on-line web presence. Mark originally started his career with the Defense Mapping Agency Aerospace Center (DMAAC) in 1977, graduated with a MA in geography from the Ohio State University in 1982, and then moved to the Northern Virginia in 1994 where he still currently resides.

Eva Siekierska

Cartographic Research Project Manager at the Canadian Centre for Mapping and Earth Observations, Earth Sciences Sector, Natural Resources Canada. Her most recent activity focuses on the development of customized, multilingual prototype maps of the Canadian Arctic. Previously she worked in the field of electronic atlases and geovisualization. Examples of products developed include: ELADA, an Electronic Atlas of Agenda 21; Historical Evolution of Canada; Ottawa Now and Then, a visualization to celebrate the 125th anniversary of Ottawa; and, Historical and Spatial Evolution of Iqaluit.

Her most rewarding project was the Internet-based (audio-tactile-haptic) maps for the blind and visually impaired, a project carried out within the People with Disabilities online interdepartmental program, for which her team received an APEX award for "a creative blend of partnerships, technology and new approach to client services to benefit Canadians with special needs." Additionally, she was appointed a lecturer at the University of Ottawa and an adjunct professor at Carleton University.

Activities in the International Cartographic Association include leading the Commission on Gender and Cartography, co-chairing the Commission on National and Regional Atlases, and serving as a member of Commissions on Maps and Internet, Visualization, and Map Use and Users. Her accomplishments are documented in over 70 papers and several book chapters. She holds a Dr. of Natural Sciences degree from the Swiss Federal Institute of Technology, ETH-Zurich and Masters degree in Cartography from Warsaw University in Poland, and is a recipient of the 125th Anniversary of the Confederation of Canada Medal.

Rebecca Somers

Rebecca Somers is a GIS management consultant specializing in GIS management and organization, program review, and strategy development. A GIS leader for more than 25 years, she has helped dozens of organizations successfully develop their GIS programs – both as an in-house GIS manager and as a consultant.

In 1983 she was the computer mapping coordinator at the City of Calgary, managing the creation of the high-accuracy parcel base map, helping city departments produce and use spatial data, and promoting the vision of GIS capabilities.

Rebecca is a prominent GIS management instructor, writer, and speaker in national and international forums, and wrote the GIS management strategies column for *Geospatial Solutions* for 10 years.

She has been involved in many significant developments in the GIS management field, including the initial GISP certification program, the URISA Leadership Academy, the GIS Management Institute, and the GIS management component of the Geospatial Technology Competency Model. She has served on many industry boards and committees including URISA, ACSM, GLIS, GISCI, FGDC, and the Penn State MGIS Advisory Board.

Rebecca holds a Master's degree in Geography, specializing in GIS, from SUNY at Buffalo.

Ralph A. Smith

Ralph Smith was born in Toronto in 1932, and completed high school in Richmond Hill, Ontario. He received a Diploma in Public Administration from Ryerson.

In 1955 while working for the Department of Highways, Ontario, he completed his cadastral survey examinations and was commissioned as an Ontario Land Surveyor (OLS). Ralph was subsequently commissioned in Photogrammetry, and as an Ontario Land Information Professional (OLIP), and a Canada Lands Surveyor (CLS). In 1970 he was made an Honorary Member of the Association of Certified Survey Technicians and Technologists of Ontario.

In 1957 Ralph was appointed Chief Roads Surveyor for the recently formed Municipality of Metropolitan Toronto. He was later appointed Administrator of the Central Mapping Agency, and then Manager of Geo-Systems Development.

Ralph served on the OLS Council and on many committees including, amongst others, Metro Toronto Public Works Coordinating Committee, American Public Works Computer-Aided Mapping and Records Management Committee, Ontario Urban and Regional Information System Association Council; OLS University Liaison Committee, and on Liaison Committees for several colleges including George Brown, Humber, and Fleming. He also served on the Ontario Land Registry Office conceptual design committee regarding the computerization of the land registry system in Ontario.

In 1990, the extension bar used in planting the Ontario Post One monument was presented to him by Metropolitan Toronto in recognition of his extensive contributions to progress in Geographic Information Management. In 1992, Ralph received the Association of Ontario Land Surveyors' Fellowship Award.

D. R. Fraser Taylor

D. R. Fraser Taylor is Distinguished Research Professor and Director of the Geomatics and Cartographic Research Centre at Carleton University, Ottawa, Canada. He has been recognized as one of the world's leading cartographers and a pioneer in the introduction of the use of the computer in cartography. He has served as President of the International Cartographic Association from 1987 to 1995. Also in 2008 he was elected a Fellow of the Royal Society of Canada in recognition of his achievements. He produced two of the world's first computer atlases in 1970. His many publications continue to have a major impact on the field. In 1997 he introduced the innovative new paradigm of cybercartography. He and his team are creating a whole new genre of online multimedia and multi-sensory atlases including several in cooperation with indigenous communities. He has also published several influential contributions to development studies and many of his publications deal with the relationship between cartography and development in both a national and an international context. In 2012 he was awarded the 3M/Royal Canadian Geographic Society Award for Environmental Innovation and in August 2013 was awarded the Carl Mannerfelt Gold Medal by the International Cartographic Association. This award is the highest possible honour in cartography and has been awarded only 12 times in the last 50 years. Further details of his work can be found at http://gcrc.carleton.ca.

Barry Wellar

Professor Emeritus, University of Ottawa, Principal, Wellar Consulting Inc., President, Information Research Board, Past President of URISA (1978), Distinguished Research Fellow, Transport Action Canada, Policy and Research Advisor, Federation of Urban Neighbourhoods, Distinguished Research Scientist, Lab for Applied Geomatics and GIS Science, University of Ottawa, Member of the GIS Hall of Fame, and former Director, Geography Awareness Week Program, Canadian Association of Geographers, was the Director of the AutoCarto Six Technical Program and Editor of the Symposium Proceedings, *Automated Cartography; International Perspectives on Achievements and Challenges.*

In 2012 he edited *Foundations of Urban and Regional Information Systems and Geographic Information Systems and Science*, a commissioned book celebrating the 50th anniversary conference of the Urban and Regional Information Systems Association.

Details about his career appointments, presentations, publications, consulting assignments, offices held, awards, and other professional matters can be found at various websites, including:

- wellarconsulting.com,
- transport-action.ca/en/wellar.html,
- geomatics.uottawa.ca,
- urisa.org,
- urbanneighbourhoods.wordpress.com, and
- slideshare.net/wellarb.

In Memoriam

This page recognizes deceased colleagues who made important contributions to the *AutoCarto Six Proceedings*, as well as to automated cartography, GIS, remote sensing, and related fields over their careers, and who no doubt would have been enthusiastic and insightful contributors to *AutoCarto Six Retrospective.*

To the best of my knowledge, which is based on personal affiliations and on communications from a number of individuals involved in the 2013 AutoCarto Six retrospective project, the following colleagues have died since the 1983 symposium:

Bob Aangeenbrug

Martin Broekhuysen

Fred Broome

Stan Collins

Dick Dahlberg

Simon Fraser

Y.C. Lee

Dave Meixler

Warren Schmidt

Marku Tamminen

Pinhas Yoeli

Their expertise, experience, leadership, and friendship are greatly missed.

In closing, it would be appreciated if any errors or omissions are brought to my attention at the earliest moment (wellarb@uottawa.ca), so that I may amend the In Memoriam page of recognition accordingly.

Barry Wellar, Editor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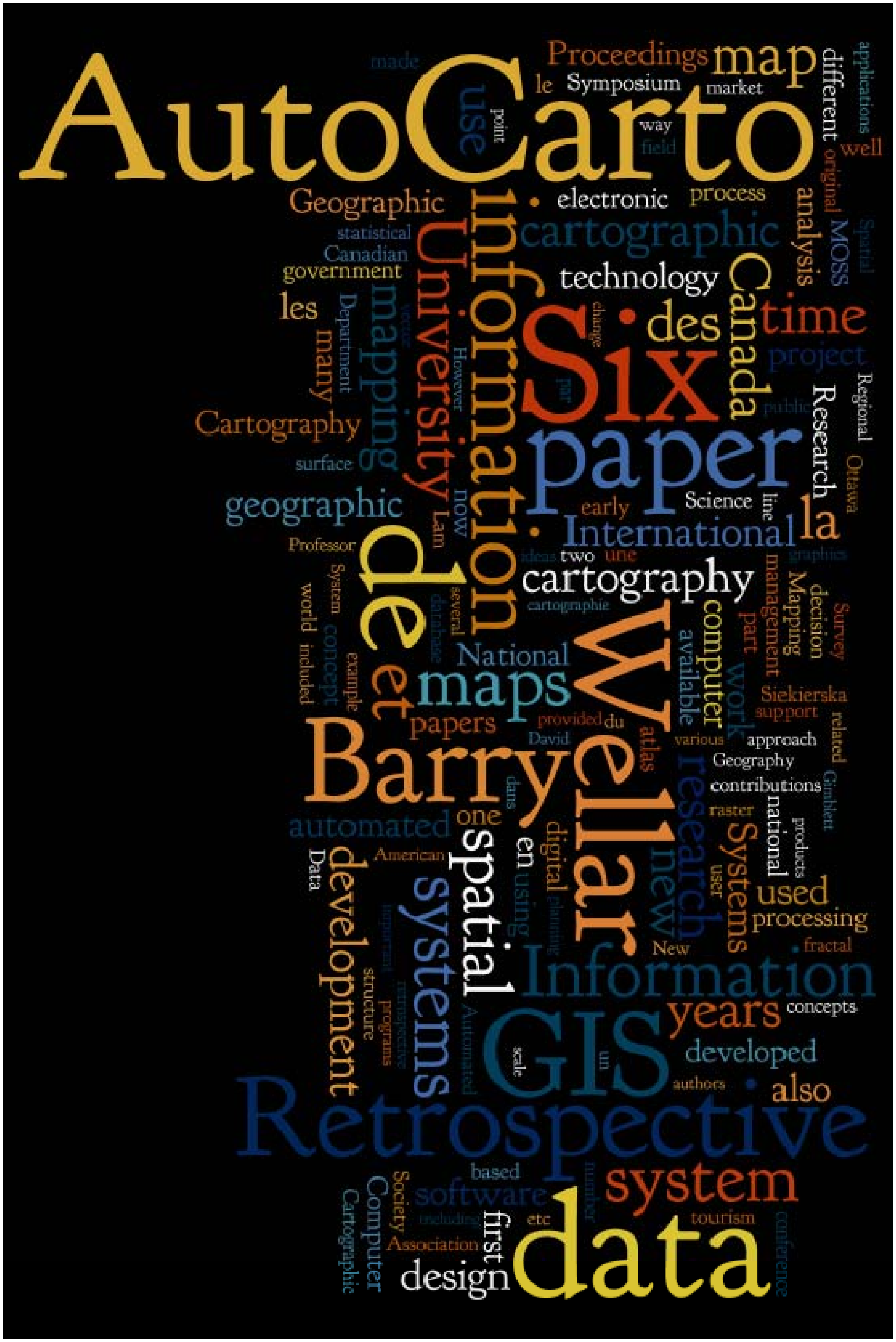
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