

– Knowledge-centric Approaches –

# From Knowledge and Meaning Towards Knowledge Pattern Matching: Creating, Processing, and Developing Knowledge Objects Targeting Geoscientific Context and Georeferencing

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## Situation and research

- This paper presents
  - the results of the **long-term research on advanced knowledge based mining enabled by conceptual knowledge frameworks.**
  - the methodological base of a new **algorithm framework of conceptual knowledge pattern matching**, allowing the consideration of complementary and descriptive knowledge of **meaning and intrinsic object properties.**
- The research is illustrated by
  - practical implementations of **knowledge pattern matching**, including processing and developing **multi-disciplinary and multi-lingual knowledge object entities and resources.**
  - Specialised research concentrates on **geoscientific context and georeferencing.**
- The goal of this fundamental research is to
  - create **methods of knowledge pattern matching usable with many resources and data collections.**
- The implemented practical approaches are first time publicly available with this paper.

# Introduction

## Knowledge Mining and tackled limitations

**Knowledge Mining** is supported by a number of common methods and algorithms, e.g.,

- string pattern matching algorithms,
- associative, comparative, and phonetic algorithms, . . . .

All these achievements deal with **distinct extrinsic properties** of respective entities in **very limited** ways.

## Motivation

**Motivation for this research was the lack of suitable facilities for an advanced matching of 'meaning'** when creating mining solutions in context of complex multi-disciplinary and multi-lingual Knowledge Resources.

# Introduction

## Intro to knowledge, meaning, and patterns forming relations

- The concept of **meaning** differs from the concept of **signification**.
- **Semantic and syntactic structures do not suffice to determine the discursive meaning of an expression [1].**
- **Discourse means a way of speaking.** On the one hand grammatically correct phrases may lack discursive meaning. On the other hand grammatically incorrect sentences may be discursively meaningful.
- **Knowledge and meaning are closely tied with intrinsic and extrinsic properties.** Therefore, understanding of intrinsic and extrinsic properties of entities is significant for any context. This is nevertheless true for any case of natural language, esp., considering **langage, langue, and parole [2].**
- Creating practical approaches requires **algorithms**. An algorithm is a process or set of rules to be followed in problem-solving operations.

# Introduction

## Introduction to fundamentals

- In general, algorithms cannot, by their fundamental nature, handle **intrinsic and extrinsic properties** to the same quality and extend. **Extrinsic properties do not reflect meaning and insight.**
- Best practice provides us with solid, complementary knowledge concepts and methodologies allowing to create advanced methods. **Data do not have or carry meaning.**
- **Cognition** (cognitio, from Latin cognoscere, “get to know”) is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses (Source: Oxford dictionary).
- **Analogy** (from Greek analogia, ἀναλογία, “proportion”) is a cognitive process of transferring information or ‘meaning’ from a particular subject, the analogue or source, to another, the target.
- Nevertheless, aspects of meaning can be described using knowledge complements, e.g., considering factual, conceptual, procedural, and metacognitive knowledge [3].
- A practical approach for knowledge pattern matching will be presented in the following sections.

# Previous work, components, and resources

## Previous work, components, and resources

- The fundamentals of terminology and understanding knowledge are laid out by Aristotle being an essential part of **'Ethics'** [4]. Information sciences can very much benefit from Aristotle's fundamentals and a **knowledge-centric** approach [3] (Anderson & Krathwohl) but for building holistic and sustainable solutions, supporting a modern definition of knowledge [5], they need to go beyond the available technology-based approaches and hypothesis [6] as analysed in Platon's **Phaidon**.
- Making a distinction and creating interfaces between methods and the implementation applications the results of this research are illustrated here along with the practical example of the Knowledge Mapping methodology [7] enabling the creation of new object and entity context environments, e.g., implementing methods for knowledge mining context.
- The means to achieve such recommendations even for complex scenarios is to use the principles of **Superordinate Knowledge**, integrating arbitrary knowledge. Core assembly elements of Superordinate Knowledge are **methodology, implementation, and realisation** [8].
- **Separation and integration of assemblies** have proven beneficial for building solutions with different disciplines, different levels of expertise.

## Previous work, components, and resources

### Previous work, components, and resources

- Comprehensive focussed **subsets of conceptual knowledge** can also provide excellent modular and standardised complements for information systems component implementations, e.g., for environmental information management and computation [9].
- For the implementation of case studies, the modules are built by support of a number of **major components and resources**, which can be used for a wide range of applications, e.g., creation of resources and extraction of entities.

## Previous work, components, and resources

### Previous work, components, and resources: UDC

- The **Universal Decimal Classification (UDC)** [10] is the world's foremost document indexing language in the form of a multi-lingual classification scheme covering all fields of knowledge and constitutes a sophisticated indexing and retrieval tool.
- The UDC is designed for subject description and indexing of content of **information resources irrespective of the carrier, form, format, and language.**
- UDC is an **analytico-synthetic and faceted classification.**
- It uses a knowledge presentation **based on disciplines, with synthetic features.**
- UDC schedules are organised as a **coherent system of knowledge with associative relationships and references between concepts and related fields.**



# Previous work, components, and resources

## Previous work, components, and resources: Processing, Facets, Patterns

- The UDC allows an efficient and effective processing of knowledge data and provides facilities to obtain a universal and systematic view on classified objects. UDC-based references in this publication are taken from the multi-lingual UDC summary [10] released by the UDC Consortium under a Creative Commons license [11].
- Facets can be created with any auxiliary tables, e.g., auxiliaries of place and space, time, language, and form as well as general characteristics, e.g., properties, materials, relations, processes, and operations, persons and personal characteristics.
- Module examples are employing Perl Compatible Regular Expressions (PCRE) [12] syntax for specifying common string patterns and Perl [13] for component wrapping purposes with this case study.

# Methodology and implementation

## Methodological algorithm base, Conceptual Knowledge Pattern Matching (CKPM)

- 1 Selecting knowledge objects.
- 2 Accessing knowledge object patterns.
- 3 Thorough processing of object entities and references.
- 4 Object entity analysis, knowledge complements' based.
- 5 Result formation.

## Accessing and processing

- Respective accessing includes organisation and structures used with the objects and entities.
- Object patterns need to be accessible to an extent and quality, which allows a sufficient processing for the respective scenario.
- Requirements for specific scenarios will therefore be individual.
- Processing includes making use of the characteristics and features of the respective implementations of the knowledge based frameworks, which provide a conceptual base for a certain method.
- Implementation and realisation: Framework providing the base conceptual knowledge reference patterns is the UDC.
- In this realisation, UDC Summary Linked Data (Main Tables, [14]). Creating facets and patterns can also make use of the common auxiliary signs [15].

# Method implementation

## Implemented method

Implementation of a CKPM based method requires accessible objects and a suitable conceptual framework base for processing & automation. The methodic implementation illustrated here enables to employ a UDC framework appropriate for systematical use.

- 1 Knowledge Resources' (KR) objects.
- 2 Accessing formalised conceptual knowledge object pattern description based on UDC, e.g., including geoscientific context and georeferencing.
- 3 Processing procedure via pipelines, employing UDC knowledge and forks.
- 4 Entity analysis, based on UDC framework references.
- 5 Result formation on base of Knowledge Resources' objects, retaining conceptual knowledge.

# Knowledge framework implementation

## Implemented conceptual knowledge framework and target: Geography ... [16]

**Table 1 :** Conceptual Knowledge Pattern Matching: Impl. UDC references of geography, biography, history (excerpt).

| <i>Code / Sign Ref.</i> | <i>Verbal Description (EN)</i>   |
|-------------------------|--|
| UDC:902                 | Archaeology  |
| UDC:903                 | Prehistory. Prehistoric remains, artefacts, antiquities  |
| UDC:904                 | Cultural remains of historical times   |
| UDC:908                 | Area studies. Study of a locality  |
| UDC:91                  | Geography. Exploration of the Earth and of individual countries.<br>Travel. Regional geography |
| UDC:912                 | Nonliterary, nontextual representations of a region  |
| UDC:92                  | Biographical studies. Genealogy. Heraldry. Flags   |
| UDC:93/94               | History  |
| UDC:94                  | General history  |

# Knowledge framework implementation

## Implemented conceptual knowledge framework and target: Geoscientific ... [17]

Table 2 : Conceptual Knowledge Pattern Matching: Impl. UDC references of mathematics and natural sciences (excerpt).

| <i>Code / Sign Ref.</i> | <i>Verbal Description (EN)</i>  |
|-------------------------|---|
| UDC:51                  | Mathematics   |
| UDC:52                  | Astronomy. Astrophysics. Space research. Geodesy  |
| UDC:53                  | Physics   |
| UDC:54                  | Chemistry. Crystallography. Mineralogy  |
| UDC:55                  | Earth Sciences. Geological sciences   |
| UDC:550.3               | Geophysics  |
| UDC:551                 | General geology. Meteorology. Climatology.<br>Historical geology. Stratigraphy. Palaeogeography |
| UDC:551.21              | Vulcanicity. Vulcanism. Volcanoes. Eruptive phenomena. Eruptions                                |
| UDC:551.7               | Historical geology. Stratigraphy. Palaeogeography   |
| UDC:551.8               | Palaeogeography   |
| UDC:551.24              | Geotectonics  |
| UDC:56                  | Palaeontology   |
| UDC:57                  | Biological sciences in general  |
| UDC:58                  | Botany  |
| UDC:59                  | Zoology   |

# Knowledge framework implementation

## Implemented conceptual knowledge framework and target: Time related [18]

**Table 3 :** Conceptual Knowledge Pattern Matching: Implemented UDC references, auxiliaries of time (excerpt).

| <i>Code / Sign Ref.</i> | <i>Verbal Description (EN)</i>                                      |
|-------------------------|---|
| UDC: "0"                | First millennium CE   |
| UDC: "1"                | Second millennium CE  |
| UDC: "2"                | Third millennium CE   |
| UDC: "3/7"              | Time divisions other than dates in Christian (Gregorian) reckoning  |
| UDC: "3"                | Conventional time divisions and subdivisions: numbered, named, etc. |
| UDC: "4"                | Duration. Time-span. Period. Term. Ages and age-groups              |
| UDC: "5"                | Periodicity. Frequency. Recurrence at specified intervals.          |
| UDC: "6"                | Geological, archaeological and cultural time divisions              |
| UDC: "61/62"            | Geological time division  |
| UDC: "63"               | Archaeological, prehistoric, protohistoric periods and ages         |
| UDC: "7"                | Phenomena in time. Phenomenology of time                            |

# Knowledge framework implementation

## Implemented conceptual knowledge framework and target: Spatial conceptual [19]

KR objects carry respective conceptual UDC facets and references, incl. georeferences.

**Table 4 :** Conceptual Knowledge Pattern Matching: Impl. UDC references, auxiliaries of spatial features and place (excerpt).

| <i>Code / Sign Ref.</i> | <i>Verbal Description (EN)</i>  |
|-------------------------|---|
| UDC:(1)                 | Place and space in general. Localization. Orientation                                 |
| UDC:(2)                 | Physiographic designation   |
| UDC:(3)                 | Places of the ancient and mediaeval world   |
| UDC:(31)                | Ancient China and Japan   |
| UDC:(32)                | Ancient Egypt   |
| UDC:(33)                | Ancient Roman Province of Judaea. The Holy Land. Region of the Israelites             |
| UDC:(34)                | Ancient India   |
| UDC:(35)                | Medo-Persia   |
| UDC:(36)                | Regions of the so-called barbarians   |
| UDC:(37)                | Italia. Ancient Rome and Italy  |
| UDC:(38)                | Ancient Greece  |
| UDC:(399)               | Other regions. Ancient geographical divisions other than those of classical antiquity |
| UDC:(4)                 | Europe  |
| UDC:(5)                 | Asia  |
| UDC:(6)                 | Africa  |
| UDC:(7)                 | North and Central America   |
| UDC:(8)                 | South America   |
| UDC:(9)                 | States and regions of the South Pacific and Australia. Arctic. Antarctic              |

# Case Example: Processing implementation

## Basic principle processing implementation

Regarding an implementation ('lxcgrep'), a basic routine preparing object entity input into a common structure is illustrated in Figure 1.

```

1  if (/^\(\\S\)\(.*\)/.~/^          /|/|^$/|/|^ *$/) {
2      s/^\(\\S.*\)\\n/\\@ENTRY\\@$1@@/;
3      s/^\(.*\)\\n/\\1@@/;
4      s/\\@ENTRY\\@/\\n/;
5      open(TMPFILE,">>$tempfile"); print TMPFILE "$_"; close(TMPFILE);
6  }
```

Figure 1: Basic routine preparing input entries (excerpt).

An associated elementary system call implementing a basic regular search is shown in Figure 2.

```

1  system("egrep -h $temppat $ARGV[0].tmp > $ARGV[0].grep.tmp");
2  system("mv $ARGV[0].grep.tmp $ARGV[0].tmp");
```

Figure 2: Elementary system call for a basic regular search (excerpt).



# Case Example: Processing implementation

## Basic principle processing implementation

An element for a simple system sort based function used with the above search is shown in Figure 3.

```
1 print "\tsorting entries...\n";
2 system("sort -f -k 1,14 <$tempfile>$tempfile.out");
3 unlink $tempfile;
```

Figure 3: Element of simple system call sort function (excerpt).

A simple backformatting routine is given in Figure 4.

```
1 print "\tbackformatting entries...\n";
2 system("perl -e 'while (<>){s/@@/\n/g;chop;print $_}' <$ARGV[0].
  tmp>$ARGV[0].sort");
3 unlink "$ARGV[0].tmp";
```

Figure 4: Simple backformatting routine (excerpt).

For further structural, technical details, and pipelining please see the references for the case studies given in the text.

# Case Example: New matching process and processing implementation

## Conceptual knowledge and red line forks

Matching is beyond non-conceptual knowledge, e.g., natural language processing and string pattern matching. Especially, country and border concepts cannot be used for specification, e.g., ancient and modern border lines fail to be useful. The process enables places in ancient Greece and Rome, from archaeological and prehistoric times associated with places in the ancient and modern world to be described, e.g., references of the type UDC: ... "63" (37) and UDC: ... "63" (38). Trigger question can be 'Can archaeological artefacts' objects of a certain context be associated with earth science objects?'. A symbolic writing specifying a conceptual expression is shown in Figure 5.

```

1  STRT: [UDC: .*?90]
2  CTXT: [[UDC: .*?\ (.??38.??\ )] | [UDC: .*?\ "6.??\ "]] .* [[UDC
   : .*?\ "6.??\ " ] | [UDC: .*?\ (.??38.??\ )]]
3  SRCH: [[UDC: .*?55] | [UDC: .*?912]]
  
```

Figure 5: Example for symbolic writing of pattern expression (excerpt).

A systematic concept of conceptual knowledge implementation allows advanced features, e.g., pattern range variations, pattern permutations.

## Case Example: New matching process and processing implementation

### Basic serial pipeline case (knowledge objects in <input>)

```

1 cat <input> | lxcgrep "'%IML:.*?UDC:.*?\(38.*?\)'" | lxcgrep "'%
  IML:.*?UDC:.*?\(6.*?\)'" <outputtxt>
2 cat <outputtxt> | lxcgrep "'%IML:.*?UDC:.*?90'"
3 cat <outputtxt> | lxcgrep "'%IML:.*?UDC:.*?55'" | lxcgrep "'%IML
  :.*?UDC:.*?912'" | lxcgrep LATLON:
  
```

Figure 6: Example for serial pipeline implementation (excerpt).

The pipeline includes objects containing and referring to latitude / longitude objects.

# Case Example: New matching process and processing

## Trackable spatial/place related fork process within conceptual pattern entity group

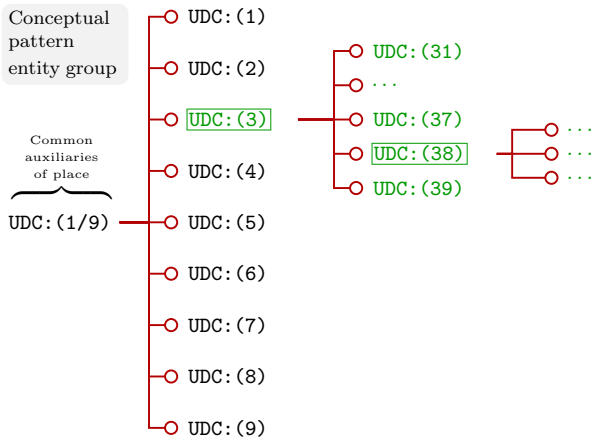


Figure 7 : Matching process: Primary, decimal (UDC) conceptual knowledge forks, auxiliaries of spatial features and place (excerpt).

# Case Example: New matching process and processing

## Fork process within conceptual pattern entity group, regarding time

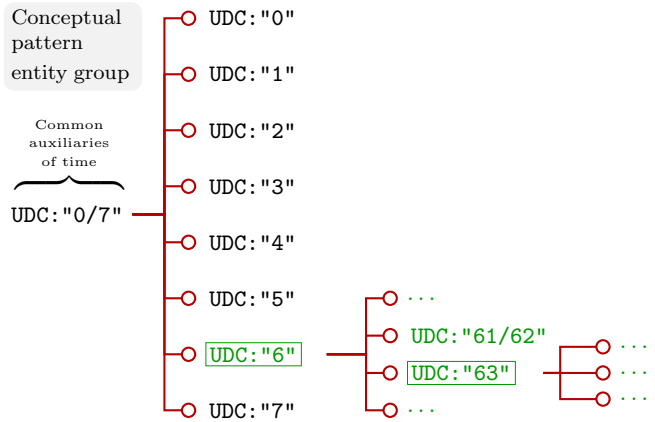


Figure 8 : Matching process: Primary, decimal (UDC) conceptual knowledge forks, auxiliaries of time (excerpt).

# Case Example: New matching process and processing

## Main tables of conceptual knowledge, within respective pattern entity groups

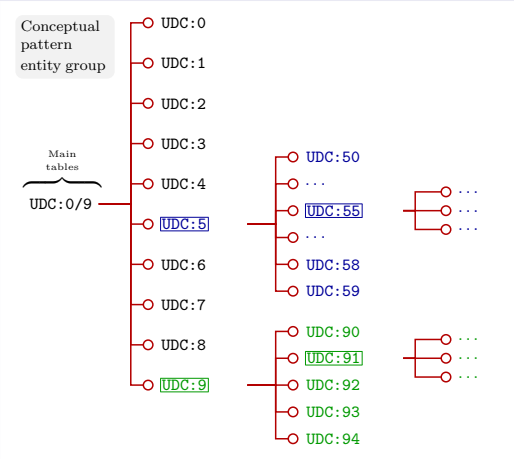


Figure 9 : Matching process: Primary, decimal (UDC) conceptual knowledge forks, main tables, including earth sciences and geography (excerpt).

# New matching process and processing

## Description and processing of universal conceptual knowledge

- These procedures referencing to a **formalised** [20], **practical framework of conceptual knowledge** embrace all the relevant universal knowledge, e.g., including natural sciences and geosciences, archaeology, philosophy, and history.
- Be aware: The results of 'removing' in the domain of knowledge and removing in the domain of mathematics are not the same.  
In principle, abstraction means removing [21].  
In the mathematical domain, removing is mostly formalised by subtraction [22].
- In general, any universal conceptual knowledge framework can be used, which enables a systematical processing and which is universal and consistent.

## Case Example: Resulting match tables

### Resulting match tables

Following the above archaeology-geosciences case of matching process and processing, the resulting match tables contain the references to conceptual and associated multi-dimensional knowledge in context of the object entities. The resulting start match table of object entities (Table 5) contains entities and references on details of mythological and archaeological context.

**Table 5 :** Resulting Conceptual Knowledge Pattern Matching intermediate start ('UDC:90') match table (excerpt).

| <i>Object Entity</i> | <i>Reference Data (excerpt)</i>                        |
|----------------------|--|
| Poseidon             | DESC MYTH SYN LOC UDC ... CITE: [23], [24], [25], [26] |
| Polybotes /-is       | DESC MYTH SYN LOC UDC ... CITE: [23], [25]             |
| Polyvotes /-is       | DESC MYTH SYN LOC UDC ... CITE: [23], [25] (transcr.)  |

These entities contain descriptions, including transcriptions, transliterations, translations, mythology references, synonyms, location references, UDC references, and citation sources. The citations refer to respective associations of the figured programme with Poseidon and the giant Polybotes / Polybotis / Polyvotes / Polyvotis and further references to the details of mythological context of realia objects, respectively to Parthenon metopes (Acropolis, Athens).



## Case Example: Resulting match tables

### Resulting match tables

The result match table of object entities (Table 6) contains entities and references on details of natural sciences context and georeferences.

**Table 6 :** Resulting Conceptual Knowledge Pattern Matching intermediate result ('UDC:55') match table (excerpt).

| <i>Object Entity</i> | <i>Reference Data (excerpt)</i>   |
|----------------------|-----------------------------------|
| Kos                  | DESC VOLC VNUM GRC LATLON UDC ... |
| Methana              | DESC VOLC VNUM GRC LATLON UDC ... |
| Milos                | DESC VOLC VNUM GRC LATLON UDC ... |
| Nisyros              | DESC VOLC VNUM GRC LATLON UDC ... |
| Santorini            | DESC VOLC VNUM GRC LATLON UDC ... |
| Yali                 | DESC VOLC VNUM GRC LATLON UDC ... |

The entities in the respective match tables contain descriptions, volcanological references, volcano numbers, country references, latitude and longitude location references, UDC references, and further references.

## Case Example: Result

## Respective result, KR object

A resulting object is shown in Figure 10. Its media object entities refer to archaeology associated with Poseidon and Polyvotis.

```

1 Nisyros [Volcanology, Geology, Archaeology]:
2 Volcano, Type: Strato volcano, Island,
3 Country: Greece, Subregion Name: Dodecanese Islands,
4 Status: Historical, Summit Elevation: 698\UD{m}. ...
5 Craters: ..., VNUM: 0102-05=, ...
6 %IML: UDC: [911.2+55]: [930.85]: [902] "63" (4+38+23+24)=14
7 %IML: UDC: [912]
8 %IML: media:...{UDC: [911.2+55]: "63" (4+38+23)=14}...jpg
9 Stefanos Crater, Nisyros.
10 LATLON: 36.578345,27.1680696
11 %IML: GoogleMapsLocation: https://www.google.com/...@36
12 .578345,27.1680696,337m/...
13 Little Polyvotis Crater, Nisyros.
14 LATLON: 36.5834105,27.1660736 ...

```

Figure 10: Result object entity from the Knowledge Resources: Nisyros object, Greece, containing media object entities (excerpt).

## Case Example: Resulting match tables

### Respective result, object references



(a) Metope, New Acropolis Museum, Athens, (CPR, DIMF, 2019).



(b) Volcano crater, island of Nisyros, Dodecanese Islands, Greece, (CPR, DIMF, 2019).

**Figure 11** : Result based on the conceptual knowledge pattern matching process, via intermediate match table (Table 6): (a) an artefact, metope (EAST VI), Parthenon, (Archaeology Digital Object Archive, 2019), and a resulting georeferenced object, (b) a natural object (Geosciences Digital Object Archive, 2019).

# Conclusion

## Conclusion

- **Goal achieved:** Created a new method of knowledge pattern matching based on the CKPM methodology.
- **Conceptual framework:** The knowledge based mining implementation employed the UDC references in order to provide the required conceptual framework.
- **Practical use:** The UDC references proved to provide an excellent core component, for universal, multi-disciplinary, and multi-lingual knowledge. In this new context, UDC showed to have a perfect organisational structure of conceptual knowledge for practical, systematical use as well as for an efficient and flexible processing support, following respective knowledge forks for references while creating and keeping developing resources and conceptual knowledge consistent supported by its editions.
- **Realisation:** The new method provides excellent and sustainable conceptual documentation and enables to create associations and links between knowledge object entities, which cannot result otherwise. Further, configuring knowledge ranges can be achieved in many ways, e.g., by limiting resources, configuring the pattern depths and widths, ranking and selection.
- **Future research** on theory and practice will continue developing suitable knowledge resources and knowledge patterns.

# Networking

**Thank you for your attention!**


# References

## References and acknowledgements, see:

- ⇒ C.-P. Rückemann, "From Knowledge and Meaning Towards Knowledge Pattern Matching: Processing and Developing Knowledge Objects Targeting Geoscientific Context and Georeferencing," in *Proceedings of The Twelfth International Conference on Advanced Geographic Information Systems, Applications, and Services (GEOProcessing 2020), June 21 – 25, 2020, Valencia, Spain* XPS Press, 2020, ISSN: 2308-393X, ISBN-13: 978-1-61208-617-0, URL: <http://www.thinkmind.org/index.php?view=instance&instance=GEOProcessing+2020> [accessed: 2020-03-22], <http://www.iaria.org/conferences2020/ProgramGEOProcessing20.html> [accessed: 2020-03-22].

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