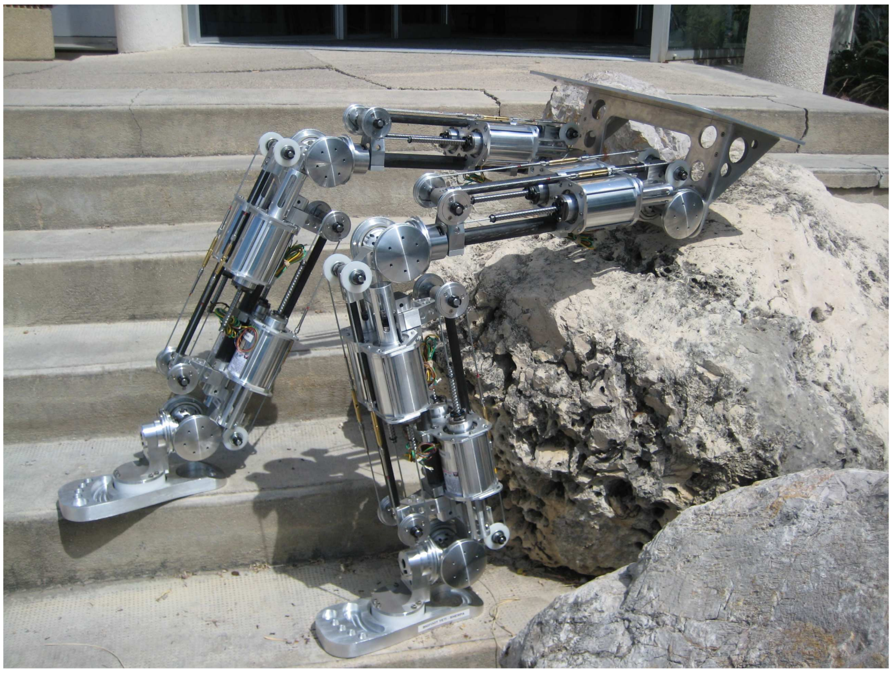
FRANCE STATUS REPORT

29th JOINT COORDINATING FORUM

INTERNATIONAL **A**DVANCED

ROBOTICS **P**ROGRAMME



A Review of Robotics Research in France

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2009 France Activity-Report-Highlights Summary

As in the past years, Robotics research in France appears as a remarkable blend of mid and long term project objectives and programmes carried on by R&D and basic research teams and laboratories. Relevant and large institutions involved comprise:

- generic research laboratories from CNRS, INRIA, and Universities,
- domain oriented organizations: CEA (Nuclear), CEMAGREF (Agriculture), CNES (Space), IFREMER (Underwater), INSERM (Health), ONERA (Aeronautics)...

All the teams contributing to research in Robotics are members of the *Groupe de Recherche (GDR) en Robotique*, an open national Research Group established by the CNRS to foster or strengthen collaborations between research teams and relationships between academics and industry. The GDR is organized in 7 working groups (WG): Medical robotics; Autonomous vehicles (land, air, sea); Multi-scale manipulation; Robotic methodologies; Human-robotic systems interaction; Innovative design and mechatronics; Humanoid robotics.

The French research policy may appear as rather complicated for other countries. In 2007, the National Research Agency (ANR) has been created, which has in charge the funding of research. We describe in this report the main call for tenders opened for Robotics, and we list most of the projects supported so far by the agency.

Several salient institutional actions illustrate the fast, dynamically evolving domain of Robotics within the frame of IARP directions:

- CNRS: the GDR, officially launched in March 2007 (http://www.gdr-robotique.fr/) continues its growth. It almost reaches the number of 900 members, including up to 300 PhD students. Salient activity developments concern the technical meetings held (18 in 2009) and the club of industrial partners (32 companies). Dedicated actions have been started for young researchers (PhD award, workshop) and for education in robotics.
- The CNRS (anticipating on 2010 Status Report) has funded this year the creation of a network of robotic platforms to improve the efficiency of the individual equipments and give access to all to advanced experimental facilities
- ANR: within the frame of the Prospective Group on Cognitive Sciences and Technologies (PIRSTEC) created in 2009, the French roboticists have been consulted on their research activities in cognitive robotics. The main result of this survey is that more than 20 research teams are involved in cognitive robotics, representing more than 240 researchers (including permanent staff, post-docs and PhD students). The research is conducted on six overlapping topics: perception, interaction, motricity, learning, bio-inspired approaches and spatial cognition.
- DGA: The General Delegation for the Arming has developed a large research program in open field mobile robotics over the last 3 years focusing on precise operational problems linking high risk missions for soldiers (mine detection and convoying and protecting against mines) and logistical tasks devoted to soldiers. The main research topics in this program concern more precisely: robot autonomy for navigation (decision sharing, obstacle avoidance, crossing over complex terrains, missions in jam signal areas), and multi-robot cooperation.
- The DGA and the ANR have jointly launched in 2009 the CAROTTE Challenge to foster collaborations between roboticists and researchers in other areas such as augmented reality, game, image analysis, indexation, semantics, etc. Each challenger is supposed to implement on a mobile platform autonomous capabilities to move in an unknown indoor environment and recognize objects for mapping purpose. The mapping should be augmented with semantic annotations.

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SUMMARY

I) *INTRODUCTION*

The present report summarizes the current French research activities in Robotics. It updates and completes the report presented during the 28th JCF in Beijing.

We introduce first the context into which these activities are developed. To this end, we give then a brief overview of how is implemented the research policy in France, in particular for Robotics. We also give a description of the current scientific and industrial context in which this research is developed. As an illustration of the topics covered, we have listed most of the projects supported by the National Research Agency (ANR) for funding. The last part of this report focuses on the different research domains developed by the working groups of the national robotic Research Group (GDR) of the CNRS.

II) *ORGANIZATION AND FUNDING OF ROBOTIC RESEARCH IN FRANCE*

Robotic research in France is mainly developed in laboratories supported jointly by the CNRS (National Center for Scientific Research) and universities. Others public research institutions as CEA, CEMAGREF, INRETS, INRIA, ONERA have also very active research teams in this domain.

Today in France, public research activities in Robotics occupy approximately 600 permanent researchers and 300 PhD students. About 100 PhD theses are supported every year in the various domains related to Robotics. These activities are developed within the framework of teams, the average size of which being about ten persons. In these research teams, interdisciplinary is strong and is growing stronger.

Robotic research activities in France are facing major scientific and technical challenges posed by modern applications in various fields. To answer better these challenges, the community joins within a "Groupe de Recherche" (GDR) in Robotics created in 2007 by the CNRS. The GDR has launched seven working groups (WG) covering methodological developments, application fields or thematic domains:

- Medical robotics,
- Autonomous vehicles (including field robotics),
- Advanced techniques in multi-scale manipulation,
- Methodologies for perception, action and learning,
- Human/robot interaction,
- Advanced design and innovative and mechatronics,
- Humanoids.

The Ministry for Higher Education and Research has in charge the piloting and strategic orientation of the French system. Within the Ministry, the head office of research and innovation (DGRI), endowed with a direction of the strategy, has a central role among the other concerned ministries in the elaboration of the national research policy. Since January 01, 2007, the policy is implemented by the National Research Agency (Agence Nationale de la Recherche ANR). Its total budget in 2009 was 820 Meuros among which 650 Meuros have been dedicated to calls for tenders.

Thematic calls for tenders from ANR are opened every year in conjunction with governmental priorities. These calls address both public research institutions and industries with a double mission of producing new knowledge and promoting interaction between public and industrial laboratories through the development of partnerships.

Today, Robotics is mainly (but not exclusively) integrated into three "thematic" programs, two of them aiming at the development of Sciences and technologies of information and communication, the other aiming at the development of Biology and health:

- **Content and Interaction program (CONTINT)** deals with the techniques related to the chain of production of digital contents: creation, capture, production, editing, access, exchange, preservation of digital contents, as well as economic model, uses, security and legal aspects. It encompasses contents for all types of media - movie, audiovisual, web, video games, sound, books - which relies on numerical techniques in production, processing, editing, dissemination storage or access phases. It also includes Robotics for transverse questions (the applications are taken into account in other ANR calls). The total budget for this call in 2009 was 35 MEuros. The call addresses the field of Robotics in synergy with the field of creation of contents and access through projects about man-machine interfaces and artificial intelligence. In 2009, the particular domain of Robotics has received 28 proposals, 3 of them being selected for funding (for a total budget of 3.2 MEuros).
- **Embedded systems & large infrastructures program (ARPEGE):** this program supports projects that develop new technology components in the following domains: embedded systems such as robotics systems, measurement and control systems, methods and tools for software design, modelling, validation and optimization, data acquisition systems; information systems; security and safety in information systems; software engineering. It promotes the place of digital processing inside objects and in our today life environment.
- **Technologies for health and autonomy program (TECSAN):** this program promotes translational research through partnerships between academic research laboratories, healthcare institutions and industries to develop new innovative technologies for the improvement of medical and surgical treatments, as well as new services and technologies for disabled and ageing people.

Along the thematic programs, the ANR is funding "non thematic" programs within the so-called "White program" and "Young researchers program" which represent half of the budget of the calls for tenders:

- The **White program** aims at giving a significant boost to ambitious scientific projects that position favorably in the international competition and that present original objectives, in break with the traditional routes of research. It is opened to all the thematics and to every types of research, from the most academic projects up to the researches led within the framework of partnerships with the socioeconomic actors. In 2010, the funds awarded by the ANR to the White program have been significantly increased to meet better the expectations of the scientific community.
- The **Young researchers program** aims at supporting the projects of young researchers or assistant professors, so as to facilitate their taking of responsibility, allowing them to develop in an autonomous way an appropriate thematic, and to give them the possibility of expressing quickly their capacity of innovation.

Robotic projects are generally submitted in one of up to 20 scientific domains of the "Information Sciences, Material and Engineering" Department of the ANR where projects are related to Machine learning, Artificial intelligence, Man-system interaction, Perception and cognition in robotics, Virtual reality, Artificial life, Multi-agents systems, Architecture of systems, Robotics bio-imitation, Autonomous decision, Planning of actions, Control, Modelling of the environment, Robotics systems. In addition, to facilitate and encourage bilateral projects, the ANR has set up translational specific agreements of cooperation with several foreign agencies. These international cooperations are very dependant to country. Robotics is registered within a particular framework with Japan only.

In addition to the "thematic" programs, the **CAROTTE Challenge** has been launched in 2009. It is oriented by the military applications of robotic systems and is supported jointly by the ANR and the DGA (General Delegation for the Arming). The aim is to make the state of the progress in Robotics in various domains (such as perception, cognition, disaster and emergency services, assistance at home, robot companion), and to foster collaborations between roboticists and researchers in other areas (such as augmented reality, game, image analysis, indexation, semantics, etc.). Each challenger is supposed to implement on a mobile platform aunonomous capabilities to move in an unknown indoor environment and recognize objects for mapping purpose. The mapping should be augmented with semantic annotations.

Others collaborative research projects is supported directly by the DGA (within the frame of the so-called **PEA-Action**, 2007-2013) that gave birth to a family of modular, semi-autonomous mobile platforms designed for military operations in urban environments. Their tactical performances are currently evaluated by the services of the land forces of the DGA. These developments are part of the French Ministry of Defence plans, which aim at developing systems and tactics that will be effective in the future close-range "contact battles" in the next 20 years. Part of this program is dedicated to virtual reality technologies which will allow the experience of being in a synthetic environment while perceiving and interacting actively and passively with it and the objects through sensors and effectors, as if they were real.

Research and innovation in France pass by directed public/private partnership research programs but also by the development of private research. This development is facilitated by an incentive **tax credit policy** (4000 MEuros in 2009) from which benefit companies that invest in R&D. and through specific actions of the ANR. A good example of such an action is the financing of the competition of innovative companies. Another example is the implementation of the so-called “**Instituts Carnot**”, the goal of which being to strengthen cooperation between the academic and industrial worlds.

A last mean of funding research worth to mention is the **Interministerial Unique Fund** (FUI) that finances collaborative research and development projects carried out by competitiveness clusters. The purpose of the FUI is to support applied research targeting the development of products or services likely to be launched on the market in the short to medium term. The fund contains 250 MEuros for the 2007-2009 period and is constituted in the Business Competitiveness Fund (FCE) under the Ministry of Economy, Finance and Industry. A substantial support, which can be estimated to 20 MEuros per year, has been brought to R&D projects in Robotics through this funding system.

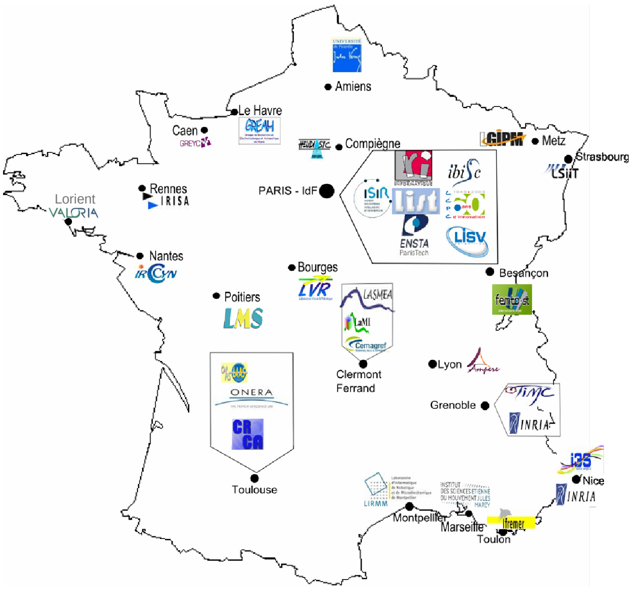
III) SCIENTIFIC CONTEXT

Robotics in France is considered as part of the sciences of information in the same way that computer sciences, control engineering, signal and image processing, disciplines with which it develops strong interactions. Robotics is then inevitably connected with the domain of applied physics. It has also natural links with mechanics, electronics and electrical engineering, mathematics (geometry, digital analysis). Most of the research teams are in academic structures of engineering sciences and information sciences.

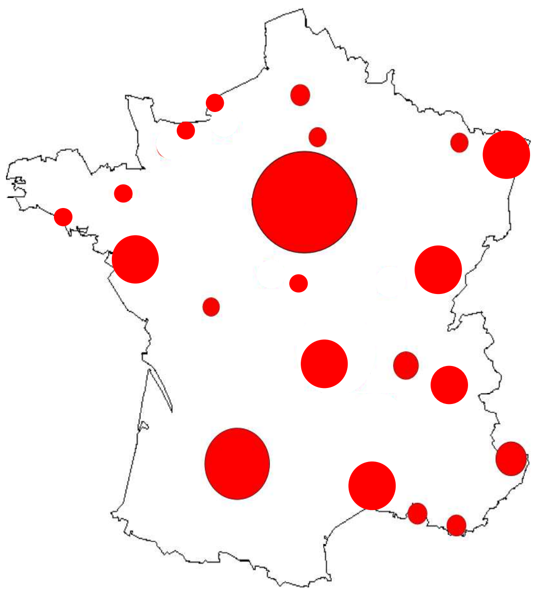
The theoretical and methodological tools as well as the technologies resulting from the robotics research activities have an impact in big business sectors as healthcare, aeronautics and ground transportation systems, spatial and submarine exploration, defense, biotechnologies, etc. This makes that research activities in France are mostly supported by the applications rather than by the fundamental research funding schemes.

The robotics research framework widened these last years to neuro-computational sciences and cognitive sciences to deal with advanced sensory and cognitive issues, physical and non-physical interactions with human beings and/or realize complex tasks autonomously in often non-structured dynamic environments. Half of the projects currently supported by the ANR associate closely engineering aspects and cognitive and life science aspects.

More than 60 research teams, distributed all over the country are active in Robotics. Each one develops its own research area, approaching robotics problems with its specific background in control, signal processing, mechanics, computer engineering. The teams have very uneven sizes according to their history, their location and scientific production, their academic and industrial environment, elements which have a major impact on their development.



Distribution of Robotics laboratories



Distribution of robotics researchers

Distribution of the academic research resources in France

IV) INDUSTRIAL CONTEXT

Industrial robotics is historic in France because it started in the 70's. In terms of installed robotic manipulators, France counts approximately 32 000 operational units (2/3 being in the car industry), among which 3000 installed in 2008, what places France in the 6th world rank, far behind Japan, the USA and Germany.

If we except collaborative projects funded by the ANR, direct partnerships between academic actors and industry in this sector are rather rare, which can be explained by the limited number of companies in the foreign competition.

Concerning personal and service robotics, field which may include surgical robotics, personnal robotics assistance, consumer robotics (vacuum cleaners, lawn mowers), playful robotics and robot companions, as well as other domains growing fast like robotics for surveillance and intervention (civil security, hostile environment), the French industry in these domains is a little more present through a certain number of small high-tech companies (Cybernetix, Robosoft, ECA, Praxim, Endocontrol, Haption, Aldebaran, Gostai, BA Systèmes, Wany Robotics, etc.) but also through large companies such as Thalès, Sagem Communications, General Electric, Dassault-Aviation, etc.

Numerous companies are developing software and technologies to cover the needs related to advanced developments of robotics. Let mention for example software companies like Dassault Systèmes (DELMIA software), ALMA, Kineo who are enablers in PLM environments for manufacturing, Bayesia and Probayes S.A who market solutions for knowledge representation using machine learning technologies; Golaem who is producing software for real-time simulations. Let also mention technological companies as BVS Tech who supplies technological components for the artificial vision, Nav on Time who provides enhanced accuracy systems for positioning and guidance of outdoor applications, Fatronik who develops technologies for development of new products / processes, Magellium in robotics sensors and platforms for a large range of applications involving mobile robots, but also large companies such as Thales Alenia Space and Astrium who designed robot system for use on the ISS and may be deployed on missions to Mars or to the moon as part of the ESA Aurora programme.

V) ROBOTICS PROJECTS FUNDED BY ANR

In what follow, we give a short description of the on-going Robotics projects funded by the ANR.

V.1) Program PSIRob 2006 (Programme Systèmes Interactifs et Robotique)

2 RT-3D

Methods of Reconstruction of Land and scene analysis exploiting a laser imager for 3D navigation in autonomous ground robots.
The project 2RT-3D discusses methods for reconstructing the 3D environment and scene analysis in a context of autonomous mobile robots moving in open outdoor environment.

Coordinator: Aubert CARREL
ANR funding: 445 355 €
Start and Duration: 08/06/07 - 36 month

BRAHMA

Biorobotics for assisting human manipulation
Within the domain of interactive robotics, the Brahma project focuses on assistance to the motion of a human subject's arm by the use of an active orthosis, an existing prototype which possesses 5 DOF, 4 of them being active. Researches proposed within Brahma are aimed toward two main objectives: i) to progress in the knowledge of human manipulation: ii) to prepare the transfer of this technology toward functional rehabilitation

Coordinator: Guillaume MOREL
ANR funding: 537 153 €
Start and Duration: 31/05/07 - 36 months

CONNECT

CONtrol of NEtworked Cooperative sysTems
The project deals with the problem of controlling multi-agent systems, i.e. systems composed of several sub-systems interconnected between them by a heterogeneous wireless communication network. In particular the project target the control of a cluster of agents composed of autonomous underwater vehicles and marine surface vessels.

Coordinator: Carlos Canudas De Wit
ANR funding: 589 129 €
Start and Duration: 05/07, 36 months

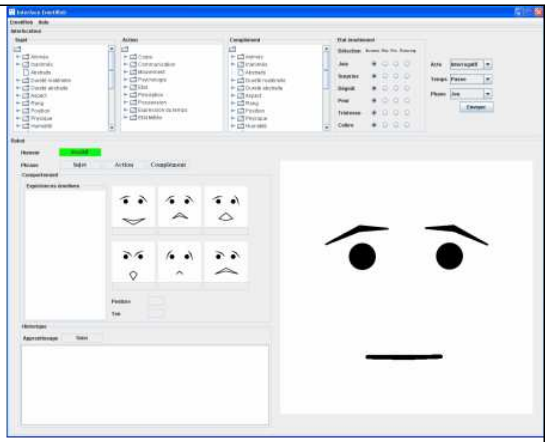
EMOTIROB

A responsive and expressive companion for vulnerable children.

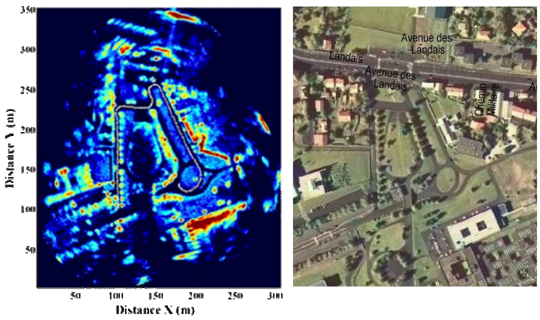
The objective of this project is to design an autonomous robot-teddy "reagent" may bring some comfort to vulnerable children (eg child inpatient long).

This project, a hundred around the detection and simulation of emotions, lies at the interface of robotics, human-machine communication and vision.

Coordinator: Dominique DUHAUT
ANR funding: 215 228 €
Start and Duration: 06/04/07 - 36 months



IMPALA



Panoramic microwave radar for locating and mapping the dynamic simultaneous external environment.

The objective of this project is to demonstrate the potential of a new microwave imaging radar for mapping and localization of mobile robots in outdoor environment.

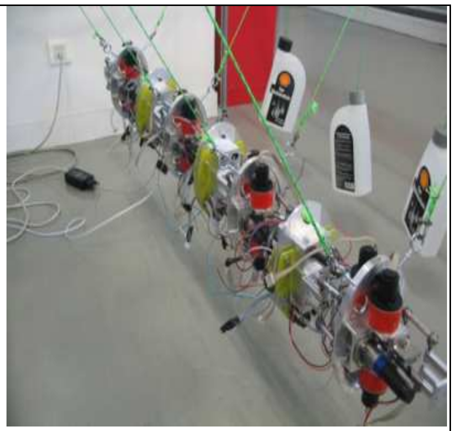
Coordinator: Marie-Odile MONOD
ANR funding: 436 503 €
Start and Duration: 08/06/07 - 42 months

RAAMO

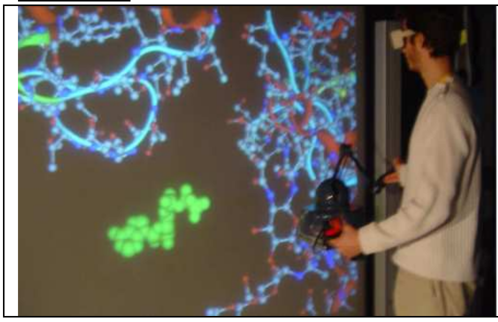
Autonomous Robot Eel in Opaque Medium

This project is part of locomotion and perception of bio-mimetic for aquatic autonomous navigation in confined and blind. It builds on the achievements of the project ROBEA "Robot - Eels" whose original purpose was "remote control operated in order to swim three-dimensional (3D) of a robot in basin. The ultimate goal of the project is to "achieve an autonomous robot capable of swimming in a confined environment."

Coordinator: Frédéric BOYER
ANR funding: 858 357 €
Start and Duration: 10/05/07 - 48 months



PACMAN



Haptic Perception of micro and nanoscale.

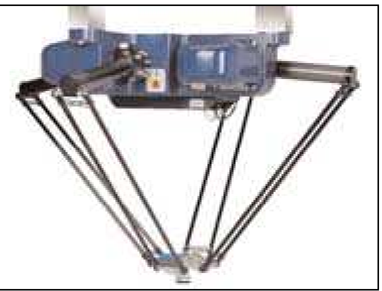
The objective of this project is to explore issues of human perception of micro-and nanoscopic scales, in the context of application handling, assembly and characterization in the fields of microtechnology and biology.

Coordinator: Stéphane REGNIER
ANR funding: 259 447 €
Start and Duration: 06/04/2007 - 36 months

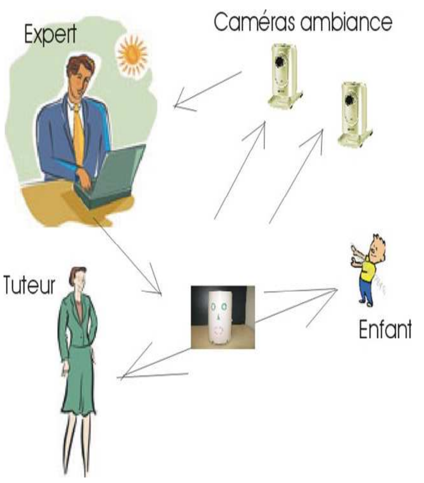
OBJECTIF 100g

The objective of this project is to explore ways to increase the pace of robot manipulation of objects by five or ten: this work must be based on scientific advances in two of the basic disciplines of robotics, design (kinematic and dynamic), and automatic.

Coordinator: François PIERROT
ANR funding: 433 758 €
Start and Duration: 07/05/07 - 36 months



RobAutiSTIC



The goals of this project must answer the following questions: how to support the interest of an autistic child by the use of a mobile robot within the framework of the play, alone and with a partner? Can one determine significant indices and reactions of the child in the play? How to deduce from the list of the behaviours of the robot those which favour these reactions and the play of the child? What is the architecture of a robot dedicated to this application? How to evaluate qualitatively and quantitatively the observed interactions and their relationships to the modifications of the interests of the child? The RobAutiSTIC project will define the models, architectures and tools implementing a robot-like environment skeletal, self-fittable and adaptive for the design and the adaptive execution of interactive play activities.

Coordinator: Gilbert PRADEL
ANR funding: 406 110 €
Start and Duration: 18/06/07- 36 months

SCUAV

Sensory Control of Unmanned Aerial Vehicles
This project is devoted to the sensor-based control of small helicopters for various applications (stabilization landing, target tracking, etc.).

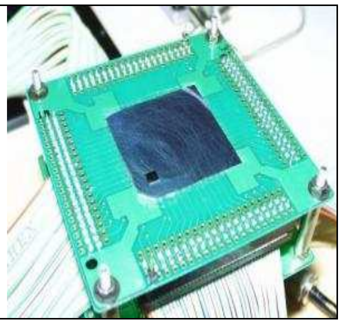
Coordinator: Tarek HAMEL
ANR funding: 819 077 €
Start and Duration: 31/05/07 - 42 months

SIROPA

Singularities of Parallel Robots.
This project aims the development of knowledge on the singularities of the direct geometric model of parallel robots, and transmission of new knowledge to future players and users of parallel robotics.

Coordinator: Jean-Pierre MERLET
ANR funding: 625 990 €
Start and Duration: 11/04/07 - 48 months

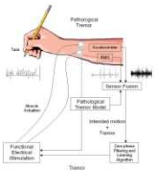
Smart Surface



Smart Surface based on autonomous distributed microrobotic systems for robust and adaptive micromanipulation.
The objective of the smart surface project concerns the design, the development and the control of a distributed microrobotic system for conveying, fine positioning and sorting of parts at meso-scale (µm to mm).
Coordinator: Nadine LEFORT-PIAT
ANR funding: 431 008 €
Start and Duration: 11/04/07 - 36 months

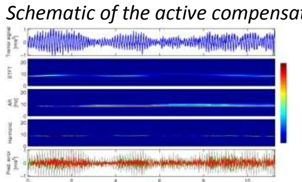
TREMOR

Tremor of upper limb



Schematic of the active compensation

Measurement system



Estimated models and prediction errors

Active tremor compensation for the upper limbs via functional electrical stimulation
The main objective of the project is then to propose an alternate solution to current pharmacological or surgical therapies that may have limited results. This alternate solution is based on the active tremor compensation of the upper limbs via functional electrical stimulation.

Coordinator: Philippe POIGNET
ANR funding: 211 620 €
Start and Duration: 19/06/07 - 36 months

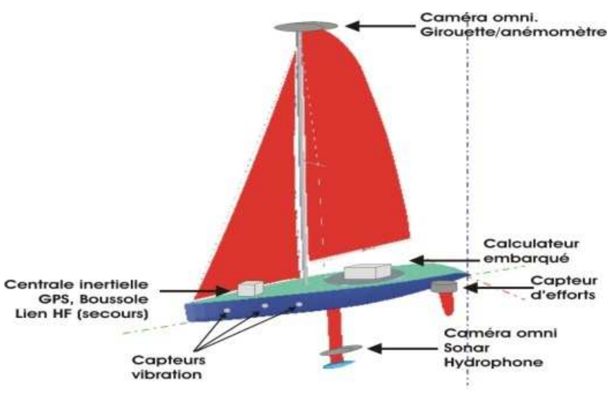
V.2) Program PSIRob 2007 (Programme Systèmes Interactifs et Robotique)

ASSIST

The "assistance" to the goal of developing an autonomous mobile robot, equipped with two manipulator arms and a vision system. It is intended to provide assistance to persons with disabilities like quadriplegics in their daily handling of objects.

Coordinator: Philippe FRAISSE
ANR funding: 845 024 €
Start and Duration: 07/07/08 - 48 months

ASAROME



Autonomous Sailing Robot for Oceanographic Measurements.
The objective of this project is to demonstrate the relevance of the use of autonomous surface craft (ASV Autonomous Surface Vehicle) to sail to the achievement of long missions (several weeks) of measurements and observations in the marine environment.

Coordinator: Robert MILLET
ANR funding: 726 395 €
Start and Duration: 30/01/08 – 36 months

AMORCES

Algorithms and Models for Robot Collaborative Eloquent and Social.

The project aims to study the interaction and operational decision-making human-robot and, more particularly, the impact of verbal and non-verbal communication on the implementation of collaborative tasks between a robot and a human partner.

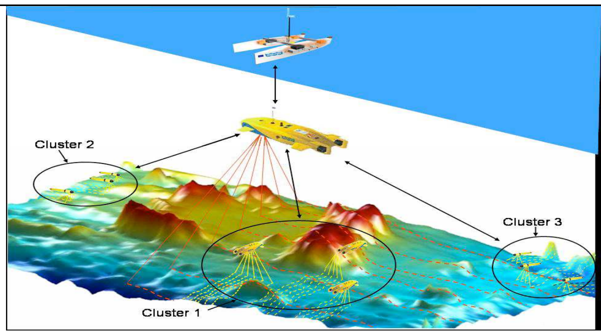
Coordinator: Rachid ALAMI
ANR funding: 823 725 €
Start and duration: 31/01/08 - 36 months

C-FLAM

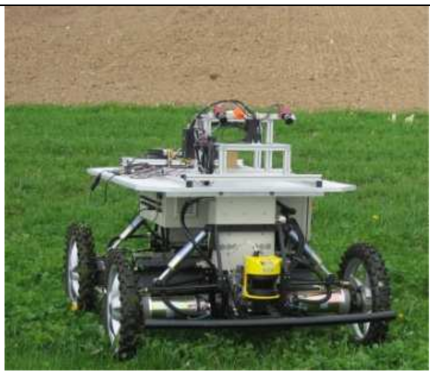
Coordination Flotilla Localization & Mapping

The objective of C-FLAM is to study solutions to coordinate fleets of mobile sensors for monitoring the marine environment, considering two main operational frameworks: mapping and monitoring of benthic regions.

Coordinator: Bruno JOUVENCEL
ANR funding: 426 416 €
Start and Duration: 12/03/08 - 48 months



FAST



Fast Autonomous rover System

The project of fundamental research FAST aims to develop a mobile robot off-road autonomous, capable of moving at very high speeds (10m / s) within a predefined corridor ensuring their physical integrity.

Coordinator: Roland LENAIN
ANR funding: 853 004 €
Start and Duration: 14/05/2008 - 36 months

LOCANTHROPE

Computational foundations of human locomotion.

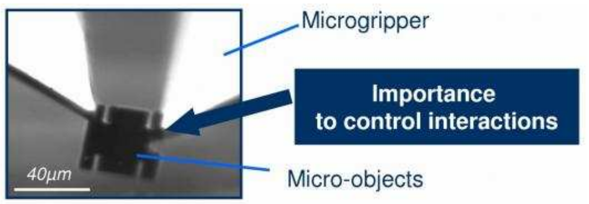
The human body is a complex mechanical system with numerous body segments. The project LOCANTHROPE argues that part of the internal cognitive state of a walking person may be observed from only few parameters characterizing the shape the locomotor trajectories. It aims at providing computational models of human locomotion as a way to simulate and plan human-like actions and interactions in both Robotics and Computer Animation. By computational models we mean models that are effective to be processed by simulation and planning algorithms.

Coordinator: Jean-Paul LAUMOND
Funding: 733 547 €
Start and Duration: 01/02/08 - 36 months

NANOROL

The idea behind NANOROL is to develop a station available for researchers and engineers in the world wishing to experiment or analyze micro/nanomanipulation tasks.
The global objective of this project is the realisation of a scientific platform which is able to analyse the microworld at a nano level the microworld to improve the robotic micromanipulation and usable by international scientists and engineers.

Coordinator: Michaël GAUTHIER
ANR funding: 576 465 €
Start and Duration: 01/02/08 - 48 months



Scope of the nanorol project

Stake of the NANOROL Project

RINAVEC

Recognition of Routes and Navigation in a convoy of vehicles communicating.
This project aims to develop and evaluate advanced features Perception and Modelling Environment for vehicles moving in convoy on a route unknown a priori, open environment (suburban or natural).

Coordinator: Frederic LE GUSQUET
ANR funding: 568 220 €
Start and duration: 11/03/08 - 36 months

RobM@rket

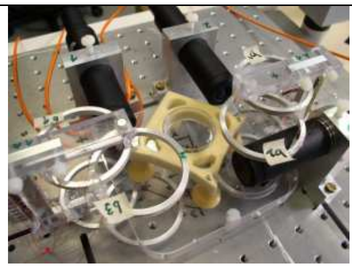
ROBo Manipulation for @maRKET
The project RobM@rket is to develop applications of automatic control preparations in a very strong sector in developing countries where the majority of tasks are manual.

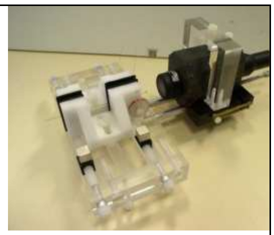
Coordinator: Guy CAVEROT
Fundind ANR: 754 054 €
Start and duration: 26/03/08 - 24 months

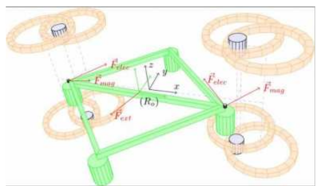
STILµFORCE

Study and Development of measuring stations of micro and nano forces in the industry. The project STILµFORCE aims to enable the company to develop a STIL control the extent of micro and nano forces in the approach of passive magnetic springs. This master password in particular through the development and reliability of two prototypes of innovative measuring stations of micro and nano forces.

Coordinator: Emmanuel PIAT
ANR funding: 829 408 €
Start and Duration: 05/02/08 - 36 months


Sensor passive levitation.


Sensor magnetic buoyancy.


Principle of floating magnetic sensor.

TELEMACH

Tele Operated Maintenance for TBMs Cutter-Head Tools.

The **Telemach** project has its origins in the tunnel construction business which is currently dominated by European contractors and tunnel boring machine (TBM) manufacturers. There is a strong requirement to build tunnels both deeper and longer in heterogeneous ground conditions which leads to complex technical problems and major safety risks. The working environment is highly restricted and often filled with slurries and crushed debris.

The project consists of developing the generic robotic technology required for replacing men by robots for the maintenance of the TBM cutter-heads in hyperbaric conditions.

Coordinator: Michel De BROISSIA
ANR funding: 786 501 €
Start and Duration: 03/02/08 - 24 months

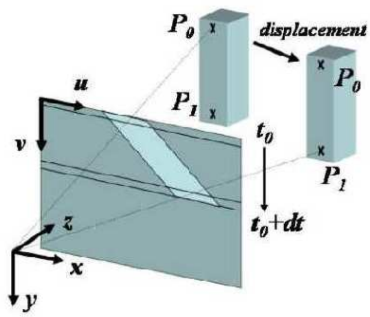
V.3) Young Researchers Program 2007

VIRAGO

New perspectives in robotics opened by high-speed vision and rolling shutter

This project studies the effects of non simultaneous acquisition of the pixels of an image or a sequence of images. It addresses fundamental computer vision geometric issues, the design of novel high-speed smart cameras and the dynamic control of robotic manipulators using such a high-speed vision

Coordinator: Nicolas Andreff
ANR funding: 180 000€
Start and Duration: 01/11/07 - 48 months



V.4) Program CONTINT 2008 (Programme Contenus et Interactions)

ABILIS

Approaches for Bio Inspired Intelligent Manipulation and Input.

This project offers two innovative methods of bio-inspired flight of an additional right hand of new generation that will be designed, conducted and evaluated. The value of integrating both methods on a single controller is to get the choice, according to the task at hand, or sequences of fine handling from scheduled tasks, or sequences based on an intuitive basis of knowledge. The second originality of this project is developing an artificial hand incorporating innovative technologies.

Coordinator: Said ZEGHLOUL
ANR funding: 823 447 €
Start and Duration: 01/2009 - 36 months

CECIL

Complex emotions in communication, interaction and language.

The goals of this project are to analyze and formalize the complex emotions in order to provide unambiguous definitions used directly by agents who know them; specify and implement a library of acts of expressive language based on previous definitions, to implement a conversational agent managing emotions and able to express the various media of expression available to him (face, body movements, speech).

Coordinator: Dominique Longin
ANR funding: 386 140 €
Start and Duration: 03/2009 - 36 months

EVA

Autonomous Flying Entomopter

The EVA project aims at developing a flying robot with flapping wings of centimeter size and weight of the gram. Compared to other projects in the world, the objective of the EVA project is to tackle the integration of embedded intelligence to make a mesorobot without joint and independent both in its energy level at its capacity for perception and action.

Coordinator: Nicolas Marchand
ANR funding: 1 137 978 €
Start and Duration: 03/2009 - 48 months

PROSIT

Robotics Platform for Interactive System in Tele-ultrasound.

The object of this project is to develop an interactive master-slave robotic platform for a medical diagnosis application (tele-echography) and to develop a cluster of ineractive functionalities combining: visual servoing, force control, haptic feedback, virtual human interface, 3D representation of organs. Within this project, we will study and develop autonomous control modes that directly make use of visual data provided by a camera observing the patient and information contained in the ultrasound image to move the ultrasound probe.

Coordinator: Pierre Vieyres
ANR funding: 1 109 365 €
Start and Duration: 01/2009 - 36 months

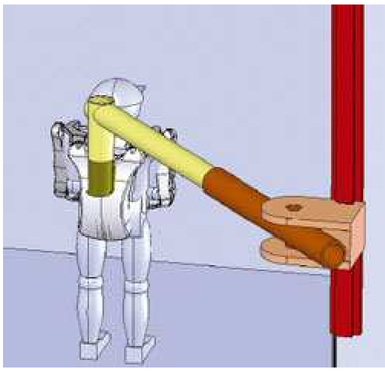
R-DISCOVER

Mobile Robot Networks : decentralized omnivision based space coverage; cooperative perception, localization and navigation.

The objectives are: i) to cover natural environments for search and rescue situations; ii) to develop decentralized networked robots and strategies for exploration and coverage; iii) to demonstrate large scale cooperative robotics for optimal visual space exploration and coverage using a small UAV and multiple UGV robots.

Coordinator: Ouiddad Labbani
ANR funding: 851 411 €
Start and Duration: 01/2009 - 48 months

SCALE1



Physical interaction at scale 1 with distant worlds.

The goal is to find a solution device force feedback allowing one or more operator (s) to work freely in one or both hands by allowing the presence of observers. This solution is based on the use of one (or two) which braces the weight and effort would be included simulated by a motor carrier. This solution must be compatible with use comfortable workstation for 8 hours within the constraints of environmental facilities.

Coordinator: François Louveau
ANR funding: 590 811 €
Start and Duration: 03/2009 - 24 months

V.5) Program CONTINT 2009 (Programme Contenus et Interactions)

IMMEMO

Immersion 3D based on the emotional interaction.
The Immemo project aims to develop a module to capture and recognize facial expressions of the person immersed (learner) to facilitate its interaction with a conversational agent which autonomously adapt the behaviour of semi-automatic to that of the learner.

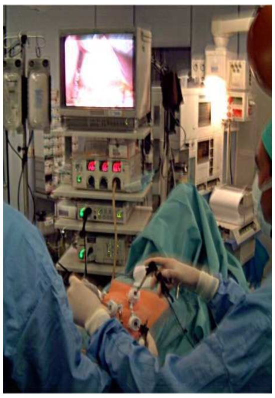
Coordinator: Renaud SEGUIER
ANR funding: 781 000 €
Start and Duration: 10/2009 - 36 months

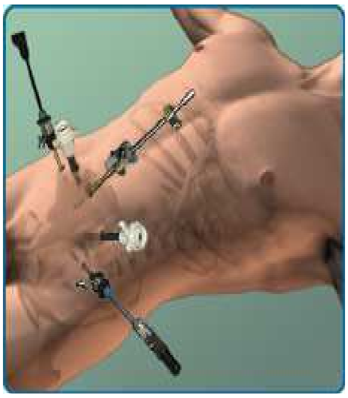
INTERACT

Towards Interactive robotics: from compliance to physical social compliance.
This project has the dual aim of creating a new type of robotic device designed for interaction with a human partner, and understanding the mechanisms of learning, motor control and execution of actions involving taking into account the gesture the object, the dynamics of the robot and the human in such a context.

Coordinator: Philippe GAUSSIER
ANR funding: 808 000 €
Start and Duration: 10/2009 - 3 years

SIME





Synergic Interfaces for Motion Extension
Obtaining a synergic behaviour of this kind of devices will be the objective of the research program: the instrument control loop shall interconnect with the operator's sensori-motor loop so that the end-effector movement and forces are controlled and felt intuitively. Therefore, the SIME project raises fundamental questions pertaining to both robotics and neurosciences.

Coordinator: Guillaume MOREL
ANR funding: 553 434 €
Start and Duration: 10/2009 - 36 months

V.6) Program TECSAN 2008 & 2009 (Programme Technologies pour la Santé)

MIRAS

Robot for Multimodal Interaction with assistance in ambulation. The objective of this project to develop pre-competitive is the design and development of a robot for mobility assistance and monitoring the physiological status of elderly people with walking difficulties and guidance.

Coordinator: Robert MILLET
ANR funding: 754 296 €
Start and Duration: 10/2008, 36 months

ROBADOM

Impact of a robot butler "at home on the psycho-emotional and cognitive development of older adults with mild cognitive impairment.
This project aims at conceiving a robot with emotions and language in order to support at home the elderly with Mild Cognitive Impairment, living alone at home and suffering or not from depression. The objective of this project is to explore the acceptability of the robot in ecological situation. This project will enable to:

- determine the appearance of the robot
- parameter the functions and behaviour of the robot for tailoring to the users' needs. The robot must be easy to use for the target population and must not be perceived as intrusive. The robot serves the elderly and is controlled by them, which enables the elderly to be more autonomous.
- evaluate the impact of the robot on elderly's daily life (affective, cognitive, quality of life...) and the way the robot is perceived.

Coordinator: Anne-Sophie RIGAUD
ANR funding: 736 316 €
Start and Duration: 10/2009 - 36 months

DEPORRA

The goal is to bring innovative tools for prostatectomy. These tools will provide the surgeon with new information from several imaging modalities (video, fluorescence imaging and US imaging), and combine them in an augmented environment. We think that this augmented environment will ultimately help the surgeon to perform his surgical gesture "optimally" and will improve the carcinologic and functionnal prognostic.

Coordinator: Sandrine VOROS
ANR funding: 1 082 523 €
Start and Duration: 10/2009, 36 months

V.7) Program ARPEGE 2009 (Programme Système Embarqués et Grandes Infrastructures)

COGIRO

Control of giant robots
The project CoGiRo deals with parallel cable-driven robots. Its main goal is to propose and validate innovative methodologies and means to control, calibrate and design parallel cable robots with very large workspaces and possibly very heavy payloads. A prototype will be built and will notably enable the experimental validation of vision-based control strategies.

Coordinator: Marc GOUTTEFARDE
ANR funding: 808 475 €
Start and Duration: 12/2009, 36 months

HORUS

User-friendly robotized helicopter for inspection.

The aim of the HORUS project is to define and to implement a distributed embedded system with a homogenous real-time communication network. The main purpose of a mini UAV is to carry sensors for the observation of hazardous and human-inaccessible environments. The prototype developed in the frame of the project will be a coaxial counter-rotating helicopter (dimensions 70 cm x 30 cm) featuring some degrees of automation: angular stabilization, localization, path planning and trajectory following, cooperation with human operators and/or other UAVs. Its mechanical structure and embedded architecture will be modular enough to easily allow carrying various payloads.

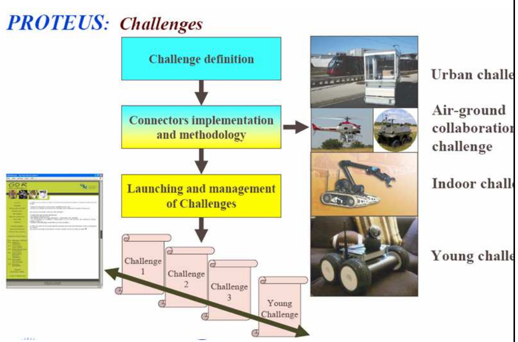
Coordinator: Boris VIDOLOV
ANR funding: 193 066 €
Start and Duration: 11/2009, 24 months

PROTEUS

Robotic Platform to facilitate transfer between Industries and academics.

The goal of the PROTEUS project is to create a portal dedicated to the French robotic community as embodied by the GDR Robotics and its associated partners' club. This portal will facilitate exchanges (knowledge, algorithms, etc.) inside and outside the community. The portal will be constituted of many parts, its software tooling one being of utmost importance to tackle with 'robotic field' concerns and 'software engineering' aspects simultaneously and to facilitate exchanges. Challenges will be organized in order to validate the portal concept and disseminate its existence throughout the community.

Coordinator: Bruno PATIN
ANR funding: 2 096 208 €
Start and Duration: 11/2009, 48 months



R2A2

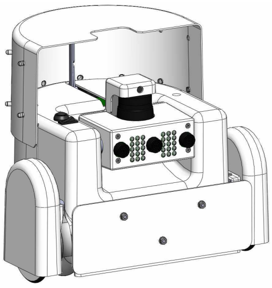
Hydraulic Humanoid Robot: Energetic Autonomy Improvement Based on Design and Control.

The goal of the project R2A2 is to improve the mechanical design of the HYDROïD robot using hydraulic actuators as well as developing walking control strategies for reducing the energy needed. R2A2 relies on modelling results (movement, anatomy) coming from biomechanics field and optimal control strategies allowing the minimum energy in term of gait cycle. This project is the combination of mechanical design and control algorithm for acting on the energy consumption.

Coordinator: Philippe FRAISSE
ANR funding: 810 554 €
Start and Duration: 11/2009, 36 months

V.8) Challenge CAROTTE 2009 (CArtographie par ROboT d'un Territoire)

CARTOMATIC



Mapping and localization of multi-robot objects: architecture, deployment technique, inter-robot positioning, and communication.
The aim of this project is to design a distributed multi-robot platform for building exploration and mapping. This project is organised around four main topics: design of an experimental multi-robot platform; localization of the robots in the fleet and mapping; design of a dedicated architecture based on multi-agent systems; object recognition using image processing combined with learning.

Coordinator: Philippe LUCIDARME
ANR funding: 350 000 €
Start and Duration: 06/2009, 36 months

COREBOTS

Design of an autonomous mobile robot embedding SLAM, vision, control and planning functions.
The project is based on the observation that many robots working in an unknown environment are tele-operated whereas existing and validated components would allow to operating them in an autonomous manner if they were properly put together. The goal of the COREBOTS project is to exploit the results of former researches and adapt them such that they can be interoperable on a robotic platform. The innovation will be to develop an appropriate methodology to integrate the required software and hardware components

Coordinator: Claire DELAUNAY
ANR funding: 350 000 €
Start and Duration: 06/2009, 36 months

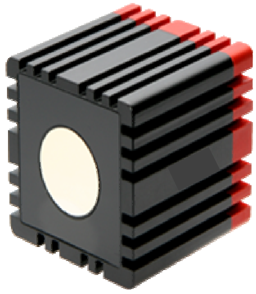
PACOM

Active and panoramic sensors to achieve semantic mapping of objects.
The way we, humans, perceive the external world appears to us as a natural, immediate and effortless task but it is done by using a number of "low-level" sensory-motor processes that contribute to our perceptual skills. The PACOM project addresses the understanding of how an autonomous embodied system can build and extract such information from sensory and sensory-motor data and generates plans and actions to explore and navigate in typical indoor environmental settings. We will therefore develop a robot that can achieve autonomous semantic 3D mapping of a large unknown area.

Coordinator: David FILLIAT
ANR funding: 350 000 €
Start and Duration: 06/2009, 36 months

ROBOTS_MALINS

<table>
<tr><td>Robots for mapping and localization making use of intelligent navigation and research.
ROBOTS_MALINS addresses fundamental issues related to the design of a robust system of self-directed autonomous fleet of robots for exploration and mapping in a dynamic and unknown environment. Theproject will provide an integrated solution to new challenges on distributed recognition and perception using a combination and incremental technique of laser and visual SLAM, 2D/3D objection detection and decentralized exploration strategy using decentralized Partially Observable Markov Decision Process (DEC-POMDP) with the most recent algorithms allowing their scalability to control the operations of the fleet of robots.

Coordinator: Abdel-Illah MOUADDIB
ANR funding: 350 000 €
Start and Duration: 06/2009, 36 months</td><td></td></tr>
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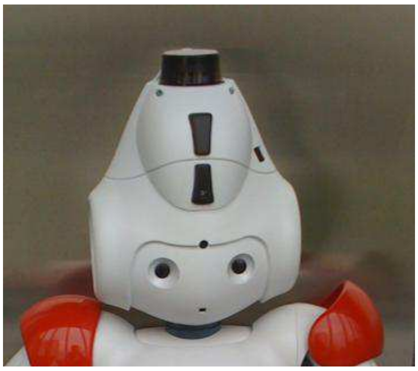
YOGI

<table>
<tr><td></td><td>Eyes, ears, legs for inspection tasks.
The YOJI project aims at using 4 humanoid robots Nao from Aldebaran Robotics working together to explore the unknown environment. The other specificity of YOJI will be to use the audio modality as an enhancement of the information coming from classical sensors: embedded vision and laser range finder. The robots, connected together through a WiFi connection, will collaborate to discover progressively the environment. A synchronization system, based on audio modality, will give them a way to get a relative localization from each other in order to make easier the fusion of collected data. Overlap of global visual maps of each robot, based on pictures taken by its camera, will allow building a general global map

Coordinator: Rodolphe GELIN
ANR funding: 350 000 €
Start and Duration: 06/2009, 36 months</td></tr>
</table>

VI) PARTICULAR RESULTS AND ACTIVITY DEVELOPEMENTS

The last part of this report aims at providing an insight into the seven working groups of the GDR Robotics:

- Medical robotics,
- Autonomous vehicles (including field robotics),
- Advanced techniques in multi-scale manipulation,
- Methodologies for perception, action and learning,
- Human/robot interaction,
- Advanced design and innovative and mechatronics,
- Humanoids.

A few examples of challenging mid- and long term objectives that are pursued in strong synergy with international partners are given.

VI.1. Medical Robotics

Objectives

Medical robotics is now a mature research field with numerous issues dealing with mechatronic design, image processing and visual servoing, control theory, haptic feedback, man machine interface, etc. A specificity is to interact with existing medical equipments for instance in medical imaging devices (MRI, CT, US, endoscopy, etc.). It addresses various fields of surgery (abdominal, brain, cardiac, orthopaedics, etc.), as well as other domains of medicine such as rehabilitation, psychiatry, etc. with sometime relationships with biology.

Several labs in France are involved in surgical robotics. Among the most active ones, we may mention TIMC-IMAG (Grenoble), LSIIT (Strasbourg), ISIR (Paris), LIRMM (Montpellier), CEA/LIST (Fontenay-aux-Roses), INRIA Lagadic (Rennes), PRISME (Bourges), IRCCyN (Nantes) and AMPERE (Lyon). The community is structured around a working group that organizes three national meetings per year. Some special events are also supported such as the summer school organized in Montpellier every two years focusing on surgical robotics. Several programs from the Research National Agency (ANR) are used by this community to get funding: Health Technology (TECSAN), Contents and Interaction (CONTINT), etc.

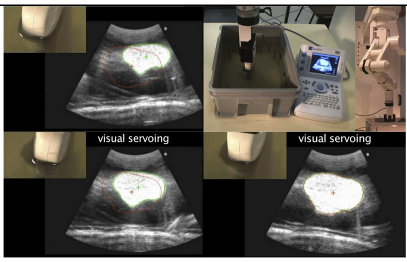
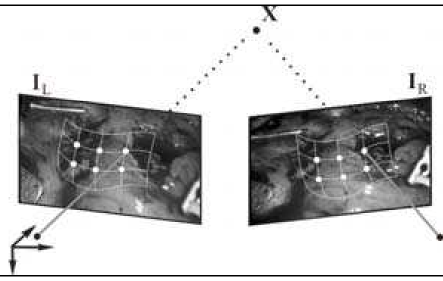
In the field of surgical robotics, the trend is now to develop dedicated / smart devices or instruments. Researchers are focusing for instance on the design of needle-holder robots, robotized guides for orthopaedic surgery, dedicated robots for transluminal or single-port surgery, active catheters or cardiac stabilizers, smart instruments. Among the issues tackled by the French research community, we may mention:

- the modelling of soft tissue deformation and tool/organ interactions,
- the real-time guidance of robots by the use of medical images such as MRI, CT or US,
- the control of instrument-tissue interaction through force feedback telemanipulation or comanipulation,
- the design of MRI / CT compatible robots to be used in interventional radiology,
- the design of robotized dexterous imaging devices for endoscopy or micro-endoscopy,
- the design of compact patient-mounted robots or smart devices used for gesture assistance in laparoscopic surgery or orthopaedic surgery,
- the design of new mechatronic innovating devices based on reconfigurable robots or array of robots for micro or single-port surgery.

In the domain of assistive technology or gerontechnology (disabled or elderly people with sensory-motor or cognitive pathologies or deficiencies), research teams are also very active (CEA/LIST, ISIR, LIRMM, etc.). The main research activities deal with objects manipulation to make the environment closer to the patient, the transfer task of people and daily life task assistance. The objective is to design safe and simplified devices that may interact easily with non-expert people and with high capacity of motion in a cluttered environment. Rehabilitation robotics has also received an increasing interest among the community. Cognitive capacities of these robots may also play a major role in their integration in the human environment.

Modelling and control

Modelling the interactions of the surgeon’s tools with the organs, the deformation of soft tissues or the physiological motion (e.g. respiratory or cardiac motion) of the patient body to take them into account in simulators or in the control architecture are key issues in the development of new robotic systems. Indeed, the complexity of the mechanical / dynamic behaviour of the tissues / organs makes the modelling very challenging. Besides this issue, the use of existing medical imaging equipments (CT, MRI, US) requires the synthesis of new innovative real-time guidance control strategies (dealing for instance with occlusion, illumination changes, poor quality of images, etc.). The figures below illustrate two examples of recent works: one is the automatic guidance of a robotized ultrasound probe by visual servoing and the other one is the 3D reconstruction of the beating heart deformable surface in real-time to be compensated for instance by a robot. Finally, the evolution of the existing surgical procedures (e.g. MIS) may also benefit from the synthesis of efficient force feedback controller.

	
Automatic positionning of a US probe with a robot (INRIA Lagadic)	3D reconstruction of beating heart deformable surface (LIRMM)

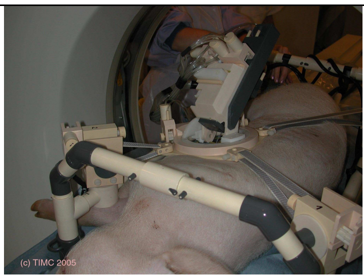
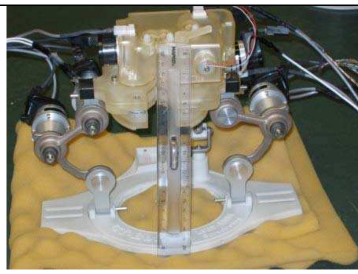
Compact patient-mounted robots

Patient-mounted robots have the advantage of naturally compensating for the patient motion (e.g. respiratory motion). They are usually compact and lightweight which make them very appropriate for use in the OR. These advantages constitute also a challenge when designing such robots that have also to be accurate and safe. One example of such robots designed by TIMC-IMAG lab is the ViKY robot that is the industrialized version of the 3-dof LER sterilizable robot that can be voice-controlled. Another example is the Praxiteles, a robot dedicated to computer assisted knee surgery.

	
ViKY - Industrial version of the LER robot initially developped at TIMC-IMAG (Endocontrol – Grenoble University Hospital)	Praxiteles / iBlock – Robot for computer assisted knee surgery (Praxim – TIMC-IMAG – Grenoble University Hospital)

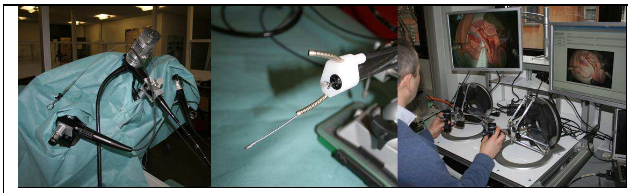
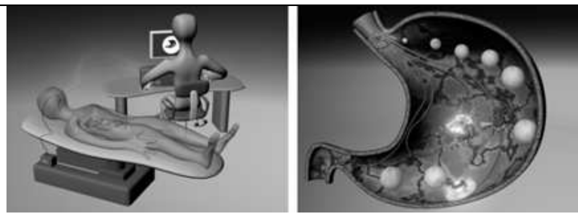
Interventional radiology

In interventional radiology, image-guided percutaneous interventions are commonly used for diagnostic or therapeutic purposes. When CT is used to guide interventions, patients and physicians are exposed to X rays. Puncture robots may then be very helpful to remove the surgeon from the operating site to limit the exposure to radiation. Moreover, the precise insertion of needles remains a challenging task under MR or CT image guidance. These features motivate the development of new robots compatible with CT, open and closed MR systems. Different robots as shown in the figure below illustrate new prototypes developped at TIMC-IMAG and LSIIT labs.

	
LPR - CT/MR compatible robot for interventional procedures (TIMC-IMAG lab and Grenoble University Hospital)	CT-BOT – a robot dedicated to percutaneous treatments in interventional radiology with X-rays exposure (LSIIT)

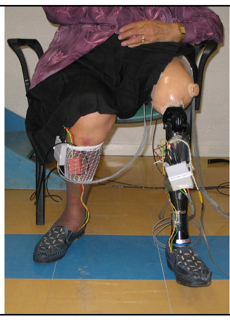
Transluminal surgery

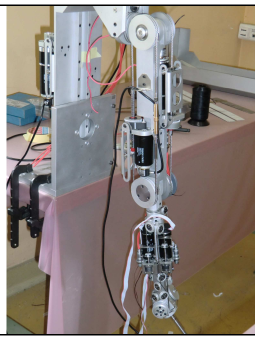
Natural orifice transluminal endoscopic (NOTES) surgery is a very recent clinical procedure. The principle consists in introducing flexible, long and thin instruments through natural orifice such as mouth and oesophagus, vagina, etc. It makes this surgery very attractive for patients because of no scar. But this new surgical approach needs then innovative developments in terms of design of micro-instruments with high degree of mobility, flexible endoscope or control strategies including for instance the active stabilization of flexible endoscope or the teleoperation of a platform equipped of several micro-robots moving inside the patient's body. Very similar issues may be considered for single-port surgery. Two projects are currently running in France as shown in picture below. Another project with single port access is starting at ISIR, focusing on dexterous exploration of the abdominal cavity for optical biopsies.

	
ANUBIS project (LSIIT – Karl Storz)	ARAKNES european project (LIRMM)

Assistive technology

Research activities focus on the design of robots or exoskeletons (e.g. the ABLE active orthosis – CEA/LIST) used for rehabilitation purposes encouraging basic movements of patients or correcting improper motions, prosthesis (e.g. lower limb prosthesis - LIRMM) or mobile manipulation robots for assisting disabled people such as tetraplegic patients in their daily-life tasks for objects grasping or manipulation (ANR Assist - LIRMM). Among the numerous issues related to these topics, researchers address human sensori-motor modelling, quality of the physical interaction between the patient and the robot, vision-based coordination and two arms manipulation, etc.

	
Lower limb prosthesis (LIRMM)	ABLE – an active othosis designed by CEA/LIST

ANR ASSIST project (LIRMM coordination)

VI.2. Autonomous vehicles

VI.2.1. Aerial robotics

In France, aerial robotics is an active research field of prime interest since the last ten years. Throughout the years, the technology has matured and continue to develop sophisticated autopilot systems for autonomous flight and navigation systems. A wide range of military and civil applications is nowadays possible due to modern embedded computing, new vision systems, sophisticated GPS positioning, low cost MEMS sensor systems, low-cost lightweight remote controlled aerial vehicles.

The commercial landscape of aerial robotics in France is composed of several major companies, whose interest in aerial robotics has become significant. Such companies are for example: Thales Group, Dassault Avation, Bertin Technologies, and a number of smaller startup companies marketing specialized platforms for specific applications (INFOTRON, NOVADEM, etc.). The growth in commercial interest has in turn fueled significant growth in research effort in the field of aerial robotics, particularly in the systems and robotics-control communities. Many of the practical challenges associated with real-time implementation of control and estimation algorithms for aerial robotic vehicles are yet to be satisfactorily resolved.

Objectives of the working group:

The main objective of the Working Group (which is associated with a Working Group of another GDR in Control theory) is to bring together researchers from both industrial and scientific communities around the UAV (Unmanned Aerial Vehicles) specific challenges to:

- identify pertinent practical and theoretical open issues, as well as efficient implementations in practical applications,
- establish and assess methodological and technological advances for the full autonomy of these vehicles.

Several scientific problems are addressed within this working group including modelling, control, visual servo control, observation, filtering, estimation and trajectory planning and also technological aspect and progress (aeromechanical architectures, sensors and actuators).

The UAV Working Group organizes at least two meetings per year. These sessions are intended to convey specific knowledge or skills; they are frequently more interactive and informal than sessions within a formal scientific program of a conference, and often involve extended discussion. They are typically scheduled for full days. Funds provided by the GDR are dedicated to invite scientists of international rank, who can provide significant know-how and input to interested members of the WG.

Main problems addressed

Aerial robotic vehicles have complex and poorly known dynamic models. They belong to the class of under-actuated mechanical systems that generally require nontrivial control techniques. The sensor systems used can be noisy and poorly characterized. The applications considered may require them to be flown closer to the vehicle performance limitations than for manned vehicles. They are often flown in close proximity to an unknown, or only partially known, and dynamically changing physical environment. They might be designed to fly indoor or in an environment where GPS signals are not available.

These practical requirements and constraints lead to a field that will benefit tremendously from the application of sophisticated control including sensor-based control approach and estimation techniques. Successful control and estimation algorithms must deal with the inherently non-linear and poorly known dynamic models of the vehicles. They should deliver global or at least semi-global stability that is robust to dynamically changing environment conditions. They must be designed with the underlying non-Euclidean nature of the state representation of a flying vehicle in mind. They should be tailored to work naturally with the sensor systems that can be effectively mounted on an aerial vehicle and deal with the high noise levels of such sensors. Aerial robotic vehicles should achieve their mission not only with increased efficiency, but also with more safety and security. Finally, the insight into behavior of flying insects, which exhibit an outstanding ability to navigate swiftly in an unknown 3D environment along with an exceptional robustness and very few computational resources, should be exploited to develop control strategies for aerial robots. Bio-inspired robotics will certainly lead to a new generation of micro-aerial vehicles.

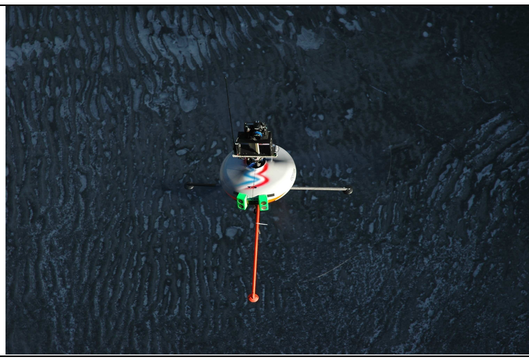
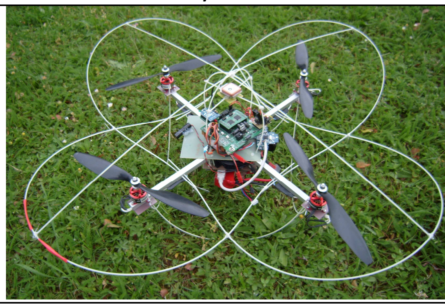
Some recent actions are listed below:

- Tarek Hamel (I3S-UNS-CNRS, leader of CONDOR team), Co-edited a Special Issue on Aerial Robotics of *Control Engineering Practice (*Volume 18, Issue 7, 2010),
- Stéphane Viollet and Franck Ruffier (Institute of Movement Sciences, Marseilles), Co-edited a Special Section on Visual Guidance systems for small unmanned aerial vehicles of Autonomous robots. (Vol. 27, Issue 3, 2009),
- Rogelio Lozano (Heudiasyc and head of the UMI LAFMIA in Mexico) edited a book entitled "Unmanned Aerial Vehicles Embedded Control" in Wiley-ISTE,
- Stéphane Viollet and Franck Ruffier, organized a Workshop on Visual Guidance systems for small unmanned aerial vehicles, IEEE IROS'08, Nice, France (Sponsored by the GDR Robotics),
- The co-organizers of the Working Group have led some invited sessions in major conferences in Control and Robotics (CDC’09, CIFA'10, IROS'08, etc.).

The main French labs involved in the UAV programs are numerous, among them:

- ONERA (Toulouse), GIPSA-Lab (Grenoble), I3S, INRIA (Sophia-Antipolis), Heudiasyc (Compiègne), Ecole des Mines de Paris, IBISC (Evry) in modelling and sophisticated control strategies,
- CEA/LIST (Fontenay-aux-Roses), ONERA, IBISC in path and trajectory planning,
- I3S (Sophia-Antipolis), INRIA (Sophia-Antipolis), INRIA (Rennes), LASMEA (Clermont-Ferrand), ISM (Marseilles), Heudiasyc in visual servo-control and Bio-inspired control strategies, CEA/LIST,
- Ecole des Mines de Paris, I3S, INRIA (Sophia-Antipolis), CRAN (Nancy), IBISC in sophisticated observers and filters,
- Heudiasyc, ISM, CEA/LIST, I3S in development of prototypes and/or convertible platforms

Several examples of prototypes developed recently are shown in the figures below.

	
The HoverEye UAV inspecting an electricity pylon (Bertin Technologies)	The UAV IT-180-05 (Infotron) in mmediate vicinity of a dam
	
The hexacopter operated at the I3S	The platform of the quadrirotor at Heudiasyc
	
The contrarotary helicopter HORUS (Heudiasyc)	The helicopter RESSAC (ONERA)
	
The OCTAVE robot (ISM, Marseilles) equipped with two bio-inspired optic-flow sensors for precise automatic terrain following	The X4-flyer of the CEA/LIST

VI.2.1. Terrestrial robotics

Objectives

The applications relying on Terrestrial robotics are numerous and become to be embedded in usual common vehicles. However new developments for transportation remain very challenging because of the complexity of the task, in particular in outdoor situations. Indeed, building a particular avoidance system for example seems to be easy using a powerful lidar sensor and in simple conditions. But how can we distinguish a pedestrian behind a car or among a crowd using low-cost systems?

Nowadays, proposed ADAS (ADaptive Assistance Systems) offer the drivers interesting functionalities most of the time aiming at improving his security (ABS, ESP). However, each time the system has to actively control the vehicle, the reliability of the decision should be very high. At the moment, these ADAS rely on proprioceptive sensors output only for which the interpretation is not really difficult most of the time. If manufacturers want to go further, exteroceptive sensors need to be integrated. In this case data analysis is much less straightforward (especially for scene analysis, obstacle detection, or localization) and involves new approaches able to deal with these complex data.

Terrestrial robotics does not only focus on transportation problems. Military or agricultural applications, civil engineering for example need the robots to improve their capabilities to evolve autonomously with or without human drivers. In this case, the autonomy requires most of the time ground analysis, obstacle avoidance, mission planning, new control laws in case of sliding...

In a general way, four issues have been identified:

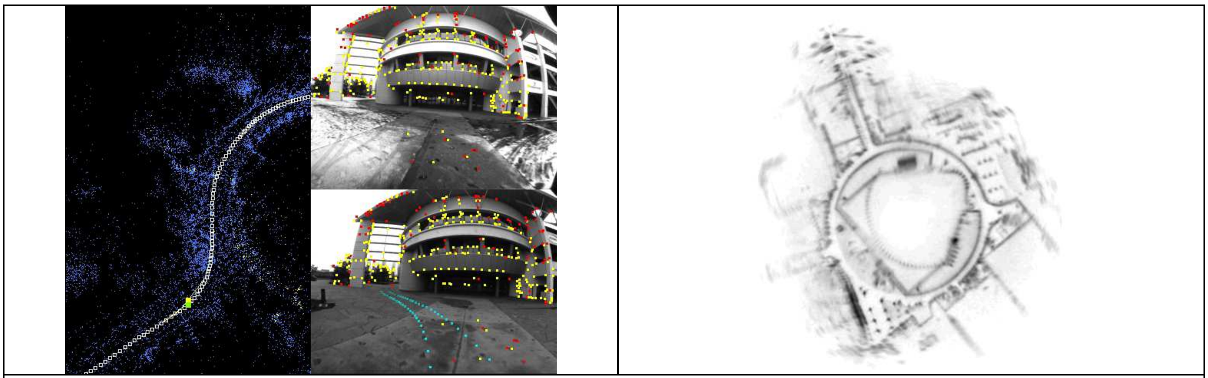
1) localization and mapping,
2) scene understanding,
3) planning and navigation,
4) robot control,
5) multi-robots.

The main French labs and institutions involved in this research areas are: Heudiasyc (Compiègne), INRIA (Sophia-Antipolis, Grenoble, Nancy and Rocquencourt), INSA (Rouen), IRISA (Rennes), ISIR (Paris), LAAS (Toulouse), LAGIS (Lille), LASMEA (Clermont-Ferrand), CEA/LIST (Fontenay-aux-Roses), CEMAGREF (Clermont-Ferrand), DGA (Paris), Ecole des Mines de Paris, INRETS/LIVIC (Versailles), LCPC (Paris).

Localization and mapping

Localization of a vehicle is most of the time mandatory to offer acceptable performance for ADAS systems. Moreover the availability of precise and complex maps or even 3D ones must be taken into account nowadays. Absolute positioning solutions (such as GPS) offer most of the time a good reliability and a good precision (a few meters). However, they are usually not sufficient to go beyond classical positioning (such as navigation help for drivers). Therefore, many works still remain to be done to improve both precision and integrity of the localization. The solutions rely on the combined use of other satellites systems (Galileo, Glonas, etc.), correction systems (WAAS, Egnos, etc.), on the use of existing car sensors, or on the maps themselves. These last solutions are very promising and allow to remove false data such as multipaths or satellites data losses. As results, several teams look now for new data fusion approaches, new modalities using deeper understanding of the data properties. Nevertheless, only using global positioning is not always possible (in particular for local localization), so challenges are now to combine absolute positioning with local one coming for example from SLAM approaches.

SLAM (Simultaneous Localization and Mapping) approaches offer nowadays the capability to localize a robot in an unknown world. Many approaches rely on lidar, camera or even radar sensors (figure below). Even if these approaches can provide interesting results, the problems of the map density, the localization drift, the use of high level features and cues in the map and how to combine absolute localization and existing maps are some of the most challenging problems researchers try to solve today.



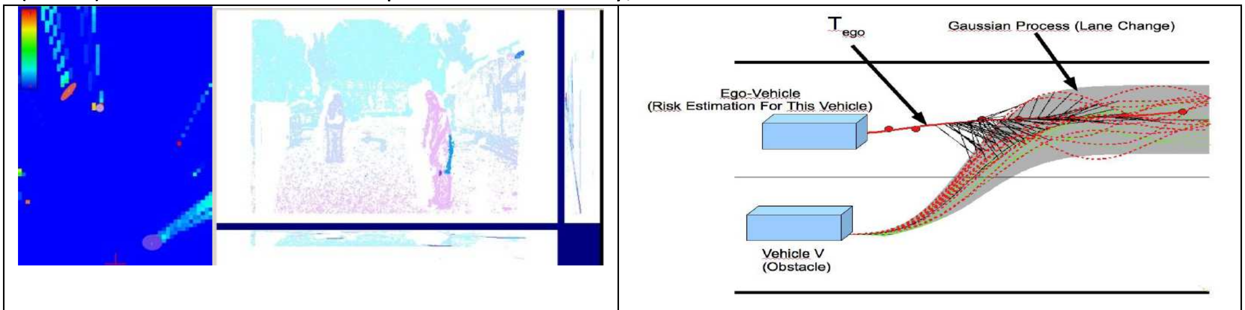
SLAM approaches (left: visual SLAM: LASMEA, right, Radar SLAM: CEMAGREF)

Scene understanding

Many ADAS need exteroceptive sensors (camera, lidar, etc.) since very challenging applications can be imagined once the different parts of the scene in front of the vehicle are extracted and recognized. As a result, the driver can be warned efficiently (figure below left). However improvements of these approaches need to consider the whole scene and new techniques need to be developed using dedicated perception systems. Other interesting issues also rely on visibility improvement (figure below middle): both driver and further processing can use such data improvements. Many work still remains to improve results, data degradation model improvement or scene shape *a priori*. In the case of autonomous robots, an important issue is the ground shape estimation. Such an analysis allows the robot to autonomously avoid holes or obstacles (crossing analysis). Combining low-cost sensors with real-time or high resolution requirements remain nevertheless very challenging even if some recent results exist (figure below right).

Left: pedestrian tracking (Renault/LASMEA), middle: visibiliy improvement (LIVIC),
right: ground reconstruction (LAAS)

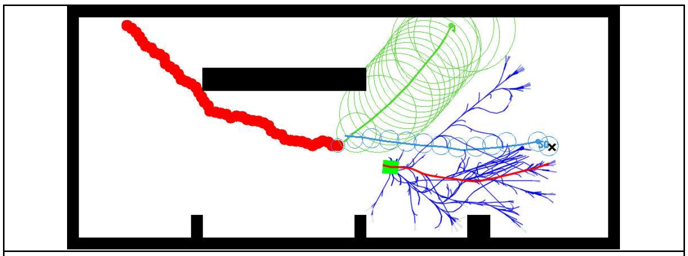
Monitoring of traffic environment and Bayesian fusion of data from multiple sensors enable to estimate and predict risks of collision as stochastic variables by using Hidden Markov Model (HMM) and Gaussian process. The scene analysis and interpretation involve detection and tracking of dynamic obstacles, environment representation, driver's behaviour recognition and modelling (INRIA). The overall result is improved traffic safety, etc.



Examples of telemetric and visual detection and tracking of dynamic obstacles	Collision risk estimation for Ego-Vehicle against Vehicle V performing a lane change manoeuvre

Planning and navigation

Autonomous navigation in populated environments is one of the most challenging topics in robotics research. This problem has been often addressed using deterministic representation, fast updating and reactive avoidance strategies. Unlike static or controlled environments where global planning is suitable, dealing with highly dynamic and uncertain environments requires to address many difficult issues: the detection and tracking of the moving obstacles, the prediction of the future state of the world and the on-line motion planning and navigation. The decision about motion must be related with the on-line perception of the world and all the sources of uncertainty involved. One way to go forward in this topic is to use collision risk assessment using a probabilistic framework (see figure below).



Collision risk assessment (INRIA Rhône-Alpes)

Robot control

Many researchers address the robot control problem. This problem is easily tractable in simple situations but remains very challenging in most of the cases where one has to cope with dynamic parameters estimation (figure below), model uncertainties, sliding effects and in particular in outdoor rough grounds. Parameters identification, robust control in presence of moving parameters, difficulties to estimate the link wheel/ground in real time, etc. remain however the future challenges.

High speed parameters estimation (Cemagref/LASMEA)

Multi-robots

Multi-robots is a recent interesting topic that can be addressed from several ways. In the case of terrestrial vehicles, we usually consider platooning. Even in flat grounds, such a fleet control remains very complex. This complexity is not only due to the difficulty to cope with a global model of the fleet but also to the conditions required by a real system such as transmission losses, latencies, localization errors, etc. Other important future issues in multi-robots is the uncentralized perception. The goal of these new challenges is to combine the data acquired from the robots in order to give a much better analysis of the whole scene. In urban environments for example, the scene understanding will be improved thanks to the combination of the data seen form different points of view. In a same way, several teams work on uncentralized SLAM aiming at both reconstruct the scene geometry but also localize all the vehicles of the fleet. However real considerations regarding transmission losses, latencies, etc., still remain difficult challenges to be addressed in the future.

VI.3. Multi-scale manipulation

Objectives

The manipulation of objects is needed in many scientific and technical processes. Broadly speaking, the manipulation is based on capture, transfer, positioning, and guidance for applications in assembly, sorting, selection of various kinds of objects. Concerning the manipulated objects, different scales can be considered:

- The macro scale: the weight of the object, its geometry and the working area set some conditions for the handling using a gripper or a dexterous robot hand,
- The micro and nano scales: the weight is negligible at this scale. These scales are mainly characterized by the fact that surface forces dominate over volume forces, leading to new complexities and paradigms in many aspects (handling principles, actuation, sensing, technologies, and control). In the same way, the influence of noise increases. For instance thermal noise has to be considered at the nanometer scale,
- The meso scale: it makes the bridge between macro world and micro world. It is still characterized by a macroscopic balance of forces (gravity forces still dominate), but also the need for vision tools for the manipulation scene adapted to this scale as well as new adaptronic solutions for the manipulators.

Grasping and dexterous manipulation

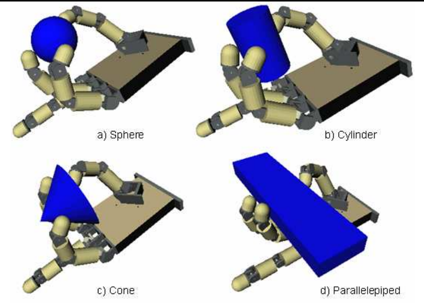
The improved functions of versatile grasp and dexterous manipulation is a need for a significant number of emerging robotic applications. Some examples from the main ones bring out the issues to be solved:

- In manufacturing environments and logistics for instance, the need is to grasp and move at high speed brittle objects of various shapes and textures (slippery or sticky). These products are currently sorted and handled manually,
- In service robotics, almost all the applications are concerned. The goal is to grasp or to manipulate in various environments objects of everyday life, either by humanoid robots or by any other robotic device,
- In medical robotics and healthcare, the grippers or hands should assist the gesture of the doctor or biologist. They must improve the work by making it safer as well as more precise. These tools are needed at all scales. Another need is the development of prostheses.

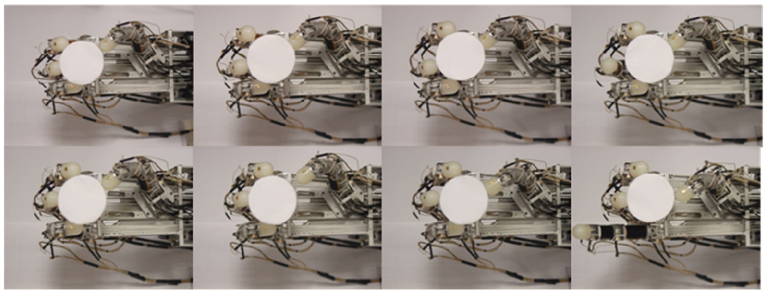
In France, research laboratories working in this field are IRISA, ISIR, LAAS, LIRMM, LISV, Pprime, CEA/LIST. The main topics addressed are dexterous manipulation, manipulation planning, grasp synthesis, control, mechanisms and actuation technology, teleoperation, underactuated hand, biomechanics modelisation, bio-inspired control and simulation.

Today, the most efficient models for dexterous manipulation that have been experimentally implemented have a quasi-static approach, assuming that manipulation is a sequence of stable grasps. In this framework, it is necessary to develop algorithms for real time force calculation and to plan the manipulation task as well as the initial grasp. Recently, several new algorithms to compute finger forces were developed. The main advantage of these methods is their computational efficiency. They are completely suited for real time applications. Furthermore, several methods for fingertip path planning and grasp synthesis including the regrasping problem have been proposed. The objective now is to build a global strategy including all the steps described above. Besides, the objects manipulated are assumed to be rigid and convex, which is not representative of daily life objects. Progress should be made in this direction.

The next step will be to take into account the dynamic effects for dexterous manipulation as well as for high speed motion of the whole system "grippers/objects". Today, most of the dynamic models implemented on existing dexterous hands do not work. Furthermore, the difficulties for the development of efficient grippers having a high-dexterity are directly related to the difficulties of integrating a large number of degrees of freedom in a small space and to the choice of an appropriate instrumentation. Therefore technological improvements should be done the miniaturization of components and the mecatronic development of new structures combining mechanisms, actuators and sensors into an integrated, inseparable system. To obtain a high-level dexterity of robotic hands, progress should also be done in sensing technology, and for example, in the development of high density tactile arrays (skin-like tactile sensors).



Grasp Synthesis



Different steps of finger gaiting using the fourth finger

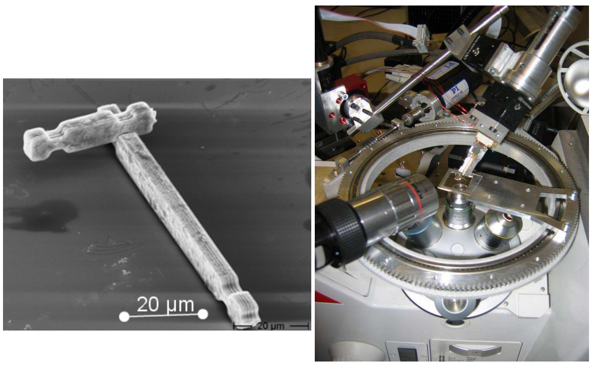
Micro/nano manipulation

The acceleration of research efforts in micro and nano robotics corresponds to several major economic and societal changes in many application fields. On the one hand, robotic solutions at these scales will bring new tools for three-dimensional and/or hybrid MEMS (Micro Electro Mechanical System) and NEMS (Nano EMS). On the other hand, innovative robotic methods will enable the development of new solutions for cell biology, biomolecules, more generally life sciences and micro surgery. At the nano scale, it will also bring new tools for nanotechnologies. Dominant physical phenomena at the micro and nano scale are often markedly different from their macroscopic counterparts. This can then modify robotic approach for manipulation and control.

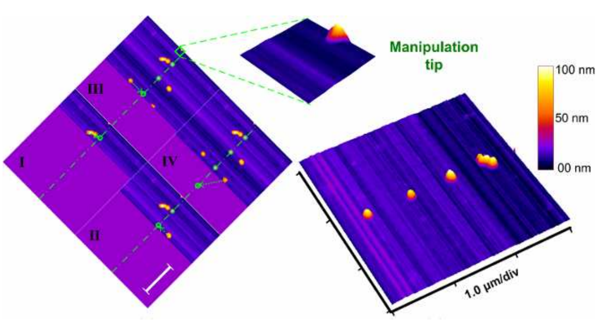
The development of micro/nano robotics has to be done in several ways. One can notably point out:

(i) The development of efficient and reliable methods for the manipulation of objects below a size of 10 microns,

(ii) The automation of micro manipulation, notably concerning micro assembly tasks for objects whose size is about one hundred micro meters.



Automatic micro assembly (FEMTO-ST)



Parallel imaging/2D nano manipulation (ISIR)

In France several research laboratories work in this field:

- FEMTO-ST (Besançon): micro handling, micro positioning, automatic micro assembly, force sensors and smart actuators, vision based manipulation, adaptronics, control of Micro systems, MEMS,

- ISIR (Paris): AFM based manipulation, haptic and force feedback for the micro/nano scale, non contact manipulation method like optical tweezers, auto-assembly, cell characterization, force modelling,
- PRISME (Bourges): haptic and virtual reality for micro scale, nano robotics,
- LISV (Versailles): laser interferometer, accurate actuator,
- CEA/LIST (Fontenay-aux-Roses): force sensor, meso-mechatronics, automatic control for the micro scale.

Strong collaborations have also been set up with:

- ULB (Belgium): capillary and electrostatic forces, EF models, adhesion.
- EPFL (Switzerland): autonomous micro robots, smart actuators, force sensors.

Among the bottlenecks addressed by these laboratories, one can mention:

- the absence of reliable models and methods for measuring interaction forces between objects at these scales, making the design of handling methods adapted to a given situation very difficult,
- the inadequacy of current vision algorithms to the specific microscopic optical systems (depth of field, low contrast) and signal processing (noise, large number of control parameters),
- the lack of high precision robotic systems with accurate and repeatable positioning in 3D (notably for rotations) for automatic tasks (micro assembly),
- the lack of integrated perception or measurement of the handling strength (typically in the range of the micro Newtons), and the development of corresponding hybrid control laws,
- the homothetic gains between nano and macro world, resulting in difficulties for the control and its robustness for example in relation to noise, or the transparency and the stability of bilateral haptic coupling.

VI.4. Methodologies for robot learning

Objectives

The number of advanced robot systems has been increasing in recent years yielding a large variety of versatile designs with many degrees of freedom. These robots have the potential of being applicable in uncertain tasks outside well-structured industrial settings. However, the complexity of both systems and tasks is often beyond the reach of classical robot programming methods. As a result, a more autonomous solution for robot task acquisition is needed, leading to robots that adaptively and autonomously adjust their programming to the encountered situations and required tasks. Learning approaches pose one of the most appealing ways to achieve this goal.

At the beginning of the 21st century, robotics research is experiencing large change in its aims and objectives. In most of the previous century, the majority of all operational robots were performing the same manufacturing task again and again in extremely structured environments such as automobile factories. By contrast, robots are now “leaving” factory floors and start becoming part of the everyday life of average citizens. This evolution raises the major challenge of “personalizing” the programming of our robots and making them compatible with human-inhabited environments. As a result, a variety of new issues arise.

First, robots will often be in physical contact with people that are not specially trained to interact with them, thus they must be less dangerous. In particular, their control loops must rely on extremely low gains while yielding sufficient accuracy, and they should never become unsafe in unforeseen situations. These considerations result in the necessity to move from the previous standard way of thinking about robot control to new approaches that more rely on on-line, adaptive model identification and autonomous action selection properties.

Second, future robots need to be more versatile and more flexible when encountering some of the infinitely many potential situations that are part of our daily life. Despite the impressive results of human manual plan design and robot programming, these hand-crafted solutions are not likely to transfer to that large variety of different tasks and environmental states. Hence, it is becoming increasingly clear that a new approach is essential. To interact better with their environment, robots will need more and more sensing capabilities but also algorithms that can make use of this richer sensory information. Due to this increase of complexity both on the perception and action side, it is becoming increasingly clear that robots need to learn the appropriate behaviour in many situations.

This challenge is becoming recognized in the general robotics community. It has resulted in supportive statements by well-known roboticists such as “I have always said there would come a time for robot learning — and that time is now” by O. Khatib (at Stanford, October 2006) and “Robot learning has become the most important challenge for robotics” by J. Hollerbach (at the NIPS Workshop on Robotics Challenges for Machine Learning, December 2007).

Main achievements

Robot learning has reached an unprecedented amount of interest in recent years. Indeed, this large shift in robotics objectives has resulted in an increasing visibility of the corresponding research lines. In the last few years, we have seen an increasing amount of robot learning publications both at top machine learning conferences (such as NIPS, ICML and ECML) and mainstream robotics conferences (particularly at RSS, ICRA and IROS). The number of learning tracks has been increasing the IEEE multi-track conferences ICRA and IROS and there have been at least 12 workshops on robot learning in 2007–2009. This development has resulted in numerous special issues in excellent robotics international journals such as the International Journal of Robotics Research, Autonomous Robots, the International Journal of Humanoid Robots and the IEEE Robotics & Automation Magazine. Recently, it even gave rise to the creation of an IEEE Technical Committee on Robot Learning.

The field being relatively new, the objectives stated above are admittedly quite far away from state-of-the-art results. But some approaches to robot learning are already giving impressive results, in particular with an approach called "imitation learning" or "learning from demonstration".

Among the most celebrated achievements in the domain, we must mention the demonstrations of HAOP3 "learning to cook" from demonstration at the EPFL in Aude Billard's team or the work from Pieter Abbeel on the Stanford Autonomous Helicopter which learnt to fly performing stunting manoeuvres using an " inverse reinforcement learning " approach.

	
HOAP3 learning to cook from demonstration (EPFL)	Stanford Autonomous Helicopter upside-down

Robot learning in France

Paradoxically, while France is a well represented country in the robot learning domain as highlighted below, there has been very few research in imitation learning in our country, apart from biologically grounded work realized in Philippe Gaussier's team at ENSEA/ETIS (Cergy).

By contrast, a lot of research in robot learning in France falls into the domain of "developmental robotics" (also called "epigenetic robotics"), whose research approach consists in applying models coming from developmental psychology to make a robot slowly building more and more elaborate capabilities, claiming that this approach may ultimately lead to capabilities that are beyond the reach of current approaches. The French research groups are well represented at an international level in this domain. In particular, Pierre-Yves Oudeyer (FLOWERS team, INRIA Bordeaux), who is one of the main promoters of this approach, recently received the highly competitive ERC grant.

Some outstanding robotic results have also been obtained in the interaction learning domain at the Robot Cognition Working Group lead by Peter Dominey at INSERM in Lyon, where humanoid robots are taught what to do through spoken language based interaction.

Closely related to the previous approach, France is also very present in the bio inspired robotics domain. Members of the SIMA team at ISIR in UPMC-Paris 6 are among the founders of that domain and Philippe Gaussier's team at ENSEA/ETIS is also very visible in that domain.

Reinforcement learning is also a very active field in France that is particularly well-suited to address some of the robotics challenges listed above. Members of the Motion team at ISIR or of the MAD group at GREYC in Caen, as well as the MAIA team at the LORIA (Nancy) contribute to the integration of advanced reinforcement learning techniques to robotics research. Some outstanding applicative results stemming from that domain have been obtained at the ONERA DCSD (Toulouse) within the ReSSAC project using the reinforcement learning framework to generate autonomous helicopter mission controllers.

Finally, following the european project RoboCub that resulted in the design of the platform, France is the only country so far to get two iCub humanoid robots (one at ISIR, obtained with the contribution of the Cognitive Robotics Group at ENSTA (Paris) and FLOWERS team, and one in Peter Dominey's group), that were designed specifically with developmental and interaction learning robotics goals in mind.

Perspectives

The field is young; it is growing quickly following a lot of various research lines, which renders any predictions about its future difficult. A lot of effort is necessary to integrate the different methods that are proposed with classical robotic knowledge. This integration is currently taking place in many robotic research laboratories and should be extremely fruitful in the next years. A gain in maturity of the field should also result in a better structuration of the growth of the field into well identified sub-domains.

VI.5. Interactions

Human-robot interaction (HRI) issues are a very challenging and still very open problem. They also constitute a domain where several disciplines might and should cooperate. More generally, interaction is in fact a key aspect of the autonomous robot. It concerns:

- Interaction between robots and humans when they have to share space and activity,
- Interaction between robots when they have to cooperate or to coordinate their activities,
- Interaction between a robot and a distant human who controls the robot at various levels of abstraction.

A scenario for a robotic assistant

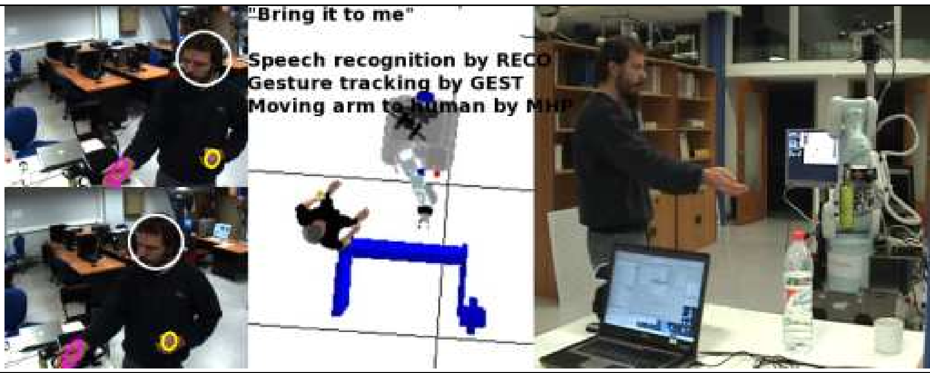
The HRI working group deals with the following issues:

- Modalities and means to exchange of communication signals that could be verbal or non-verbal, as well communication of intention and of socio-emotional signals,
- Cooperation and coordination between robotic systems and humans and issues linked modalities and processes to share space, decisions and tasks,
- Interaction with complex systems such as multi-robots, ambient intelligence environments
- New Human-robot interfaces such as haptics or brain-machine interfaces,
- The convergence between virtual reality and robotics from the interaction point of view: communication, real or simulated perception, cooperation.

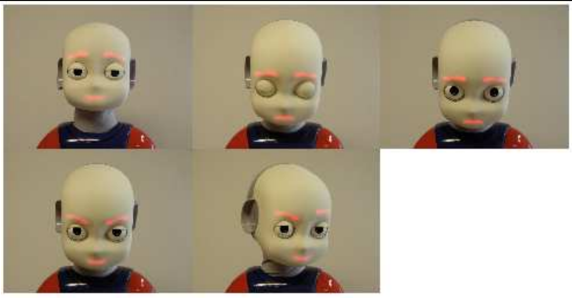
Besides, several issues have been identified that could be considered as orthogonal to the above-mentioned topics: the evaluation of interactive systems and the necessary adaptation and flexibility of the desired systems since they will have to interact with a large variety of persons in various contexts.

Communication signals and means: the community studies this topic from the point of view of perception and situation assessment as well as from the point of view of the synthesis of behaviours, gestures and sounds which convey the desired information in a given context.

Another key aspect is the study of the so-called cognitive and interactive robotics that is seen as necessary to develop effective robotic assistants in semantically rich environments. This assumes the study of the relevant control architectures, the development of the so-called human-aware task and motion planners. Such a context opens large avenues to learning and more generally to adaptive schemes. Sociological and psychological issues of relevance and acceptability of robot behaviour are also of high pertinence and interact heavily on the global design of the overall systems.

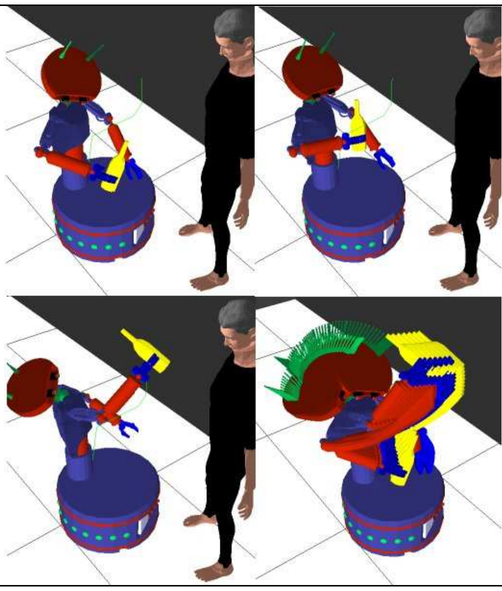


Interpretation of multimodal commands by the robot (left: hands and head tracking; center: synthetic top view; right: experiment)

	
An embodied Conversational Agent	Face expressions on an Icub robot

The future interactive robot will have also to interact with ambient intelligence systems, sensor networks and all kinds of sub-systems capable of communication and/or of action on the environment (the Internet of things). This calls for models, algorithms and software to cope with the complexity and variety and of the interactions.

The teams involved in this field contribute at the national, European and international level: IBISC (Evry), INRIA (Rennes and Sophia-Antipolis), ISIR (Paris), LAAS (Toulouse), LIRMM (Montpellier), LISSI (Créteil), LTCI (Paris), VALORIA (Lorient), CEA/LIST (Fontenay-aux-Roses). They are particularly active in several national (ANR) and European (IST FP6 and FP7 frameworks) projects.



Planning a legible and safe motion for handing over an object

	
Social robotics	Brain computer interface for interacting with a robot

Ubiquitous robotics

VI.6. Innovating design and mechatronics

Objectives

According to the Robotic Industries Association, the North American robotics industry grew at an average annual rate of 20% from 2003-2005. Taking into consideration a relatively soft automotive market and increased pressure from overseas manufacturers, how has this strong growth occurred? An ongoing trend of cost reduction has been one factor: the price for both robots and overall turnkey systems has continued to decline. Also driving the strong growth is the continually improving performance of robots: robots can perform tasks today that were not possible just a few years ago. At last, robots can do more in less time, providing higher level of productivity.

As shown in the “EURON research roadmaps” of 2004 as well as in several Japanese studies, the development of service robotics, the assistance to sick people or elderly, and domestic robotics will grow considerably in the next ten years. For more specific applications, such as surveillance, interventions in hostile or dangerous environment (nuclear, underwater, vulcanology), the development of new robot structures is also required.

The contribution of French laboratories (Ampère (Lyon), CEA/LIST (Fontenay-aux-Roses), INRIA (Sophia-Antipolis), IRRCyN (Nantes), ISIR (Paris), LaMI (Clermont-Ferrand), LGPIM (Metz), LIRMM (Montpellier), LISV (Versailles), etc.) in the design and integration of innovative robots is very significant. It can be classified into three main topics: Methodology of design, Robot architecture of the future, Innovative components and mechatronics.

Methodology of design

The methodology of design in robotics evolved these last years. The design must account for new constraints induced by the increase in productivity of the robots (in particular of the industrial manipulators), a better adaptation to the tasks, a reduction in the costs, and a better choice of kinematics links, of the structure materials and of the actuators. The reduction of costs and the saving of material and energy increase the importance of the design and of the optimization of the robot structure. The tradeoff between these various criteria is obtained by analysis of the Pareto frontiers. The design itself can be based on methods resulting from other domains, such as product design, collaborative design, task oriented design or design of special machines. For the robotic systems intended to be in relation with a very varied public, the customer oriented design taking into account perception and preferences of the users is to be privileged.

Innovating approaches of design (for example, biorobotics founded on the comprehension of nature) and of' integration (mechatronics) are central to realize systems providing complex functions while satisfying many constraints (size, mass, integration, precision, autoreconfiguration, reliability, energy autonomy, but also for example, biocompatibility, acceptance by the user, etc.). The design must cope with a necessary process of standardization.

Besides, it is necessary to integrate kinematic and dynamic behavior from the beginning of the phase of design. This analysis must integrate modelling of flexibilities of the structures (series, parallel, hybrid) and/or of the transmissions, as well as robustness with respect to machinig errors, sensor inaccuracies, and control law performance.

Robot architectures of the future

An important topic in the robotic community is the development of methodologies to find the best adapted architectures with respect to a given application. Applications can be found in production robotics (manufacturing industry), medical robotics, service robotics (domestic service, dependent people, etc). The axes of development are based on structural synthesis of the mechanisms, innovation, and kinematic and dynamic modelling. The simulation of the real behavior of the robotic system in its environment is necessary and the identification of the parameters of the links (unilateral contact, slipping contact, modelling of frictions) makes it possible to better model the behavior for a specific application.

Among the architectures studied, one finds parallel architectures, reconfigurable architectures, spreadable or flexible or elastic architectures, the virtual human, special machines of production, strongly redundant structures. The evolutionarity of the robot depends considerably on its architecture: reactivity, modularity, reutilisability, adaptability and analysability are as many required properties. A challenge of the years to come is to propose a software framework in order to address these problems.

The applications of mobile robotics also result in being interested in the design of arms intended for handling connected to a mobile base. The design of the whole system requires reconsidering the criteria of optimization of each part.

The dynamic modelling of parallel robots, including flexibilities of these systems, forms an integral part of research on future architectures. New methods of actuation must also be studied (under-actuation and over-actuation, co-actuation, distributed actuation, reversibility, etc.).

Innovating technological components and integrated actuators, mechatronics

When building a robotic system, the choice of the elementary components (elements of structure and links, actuators, sensors, storage of energy, control unit) is decisive as it determines the global performance of the system and the correct execution of the tasks. It is then important to improve the individual performance of each component. Concerning the actuators and the mechanical drive parts, the objective is to increase the power/weight ratio and the torque/weight or force/weight ratios, while minimizing size and improving efficiency. Direct drive actuators or continuous variable gear ratio devices prove to be very advantageous for certain robots. Linear actuators could be a key factor in the evolution of certain architectures, in particular for parallel robots.

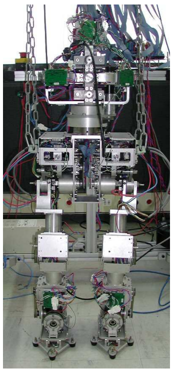
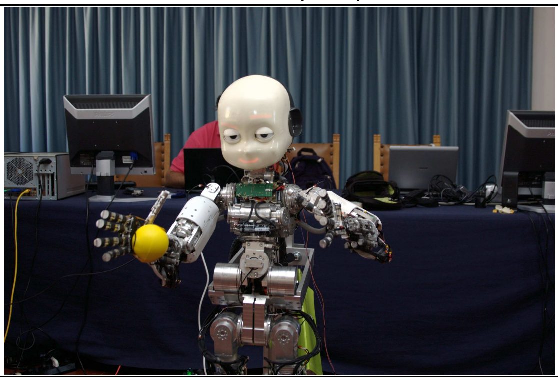
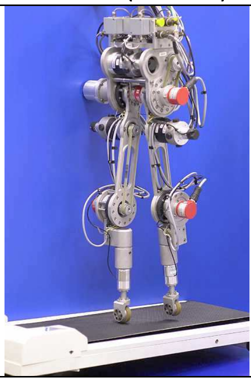
For personal assistant robots, service and toy robots, the reduction of costs is a key issue. This requires the development of low-cost, compact, and precise sensors, connected by a bus to the controller. Therefore, mechatronic plays a central role in the integration of components, in particular via standards of bus, of sensors and energy networks. Intelligent sensor technologies have contributed a lot to the successful use of robots in a variety of applications. As these technologies continue to advance, together with progress in miniaturization and mechatronic integration, robots will have even greater capabilities in the future.

VI.7 . Humanoid Robotics

Objectives

Research issues in humanoid robotic focus on four topics: mechanical design for new anthropomorphic structures, modelling, control, and path planning. Many efforts are done to fill the gap between the life sciences and robotic communities, facilitating discussion on common challenges as for instance human and humanoid motions. The scientific activity involves an increasing number of laboratories, among which INRIA (Grenoble), IRRCyN (Nantes), ISIR (Paris), LAAS (Toulouse), LIRMM (Montpellier), LISV (Versailles), Pprime (Poitiers). Several experimental platforms have been developed or are currently under development: Rabbit (IRCCyN), Robian (LISV), HRP2 (LAAS), HOAP-3 (LIRMM), Sherpa (LIRMM), ICub (ISIR) as shown on the pictures below. The following salient actions illustrate the fast growing of research and dissemination efforts done in this domain:

- Organization of an annual workshop since 2006 (two days, single track) entitled JNRH (Journée Nationale de la Robotique Humanoïde, National Days of Humanoid Robotic): JNRH'06 (LAAS), JNRH'07 (LIRMM), JNRH'08 (LISV), JNRH'09 (IRCCYN).
- Jean-Paul Laumond (LAAS, Leader of Gepetto project team) is the general conference chair of the 9th International Conference of Humanoid Robots, 2009, Paris.
- The research activity relies on the French-Japanese Joint Robotic Laboratory (JRL) hosted by LAAS-CNRS (J.P. Laumond and E. Yoshida) in France and AIST (A. Kheddar, K. Yokoi) in Japan.

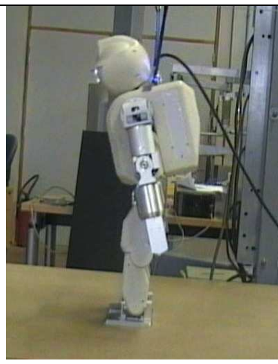
	
ROBIAN (LISV)	SHERPA (LIRMM)
	
ICub (ISIR)	RABBIT (IRCCyN)

Study and mechanical design of advanced anthropomorphic structure

This topic covers the mechanical design of new anthropomorphic system including legs, hands and feet. It works in synergy with micro technologies for reducing the size and weight of actuators and sensors as well as the energy consumption for improving the robot autonomy.

Life sciences and humanoid robotic interaction

This topic is intended to foster collaborations between life sciences (biomechanics and neurosciences) and humanoid robotics. The objective is to exhibit, from experimentations on human being, some information on postural coordination in order to extract relevant data for supplying humanoid robotic control strategies (see pictures below). These experimentations on human being can also provide information about muscle properties during walking, running or jumping and theirs effects on the dynamic performance. In turn, the robotic researchers provide to the life sciences community mathematical models based on control scheme of humanoid robot being able to reproduce the human movement. This collaboration proved to be fruitful and should be extended to studying neuromuscular disability by providing analytic model for quantifying the period of time to make a full recovery.

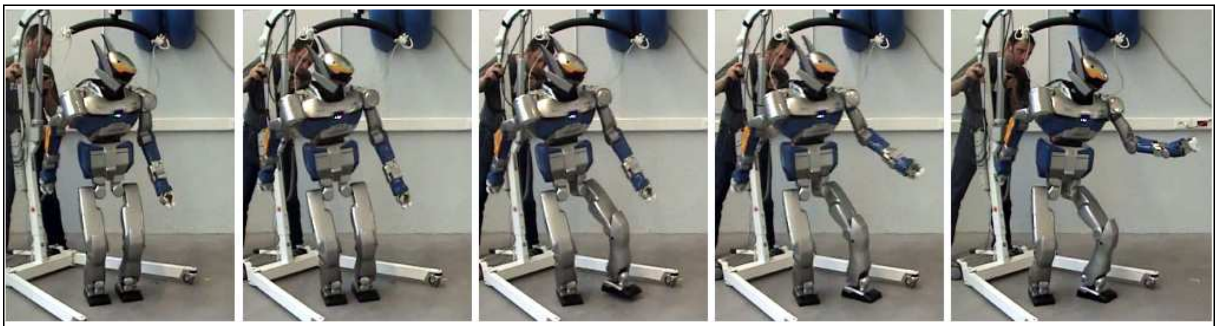
	
Postural coordination modelling on human (EDM)	Closed-loop control scheme on HOAP-3 reproducing human postural coordination (LIRMM, EDM).

Modelling and control

The balance control on humanoid robots in vertical stance or walking phase is a scientific challenge in terms of modelling and control. From the modelling point of view, we aim at studying the force impacts between the ground and feet during different movement phases such as running, walking or jumping. From the control point of view, there are new issues about stability and robustness of humanoid robots that we are addressing by considering the unilateral constraints (contact forces).

Optimization and task planning

The high number of degrees of freedom in the joint space of anthropomorphic systems is very challenging in terms of redundancy management as well as motion planning. In this topic, we aim at defining a new approach based on movement allowing path planning by using a sub-manifold of the configuration space as well as accounting for the cost functions and constraint determining the efficient movement for a given task. The series of picture below shows an experimentation of sideways reaching task.



Experimentation of sideways reaching task with HRP2 (LAAS)

VII) CONCLUSION

France is quite active in the field of Robotics Research. It counts a significant number of research laboratories with an international visibility, whose activities are mainly supported by the ANR. We estimate at approximately 30 MEuros the public funding dedicated to academic and industrial research in Robotics in 2009.

The number of PhDs in the field of Robotics delivered this year is about 80 at the national level (0,7 % of the French engineering PhD in 2008). This level of activity should be maintained and even strengthened in the next years. In particular, personal robotics, which brings new research problematics and somehow pulls industrial dynamics, should contribute significantly to this development.

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