BIANNUAL REPORT 2009 2010

Institut de Robòtica
i Informàtica Industrial

CSIC UPC

BIANNUAL

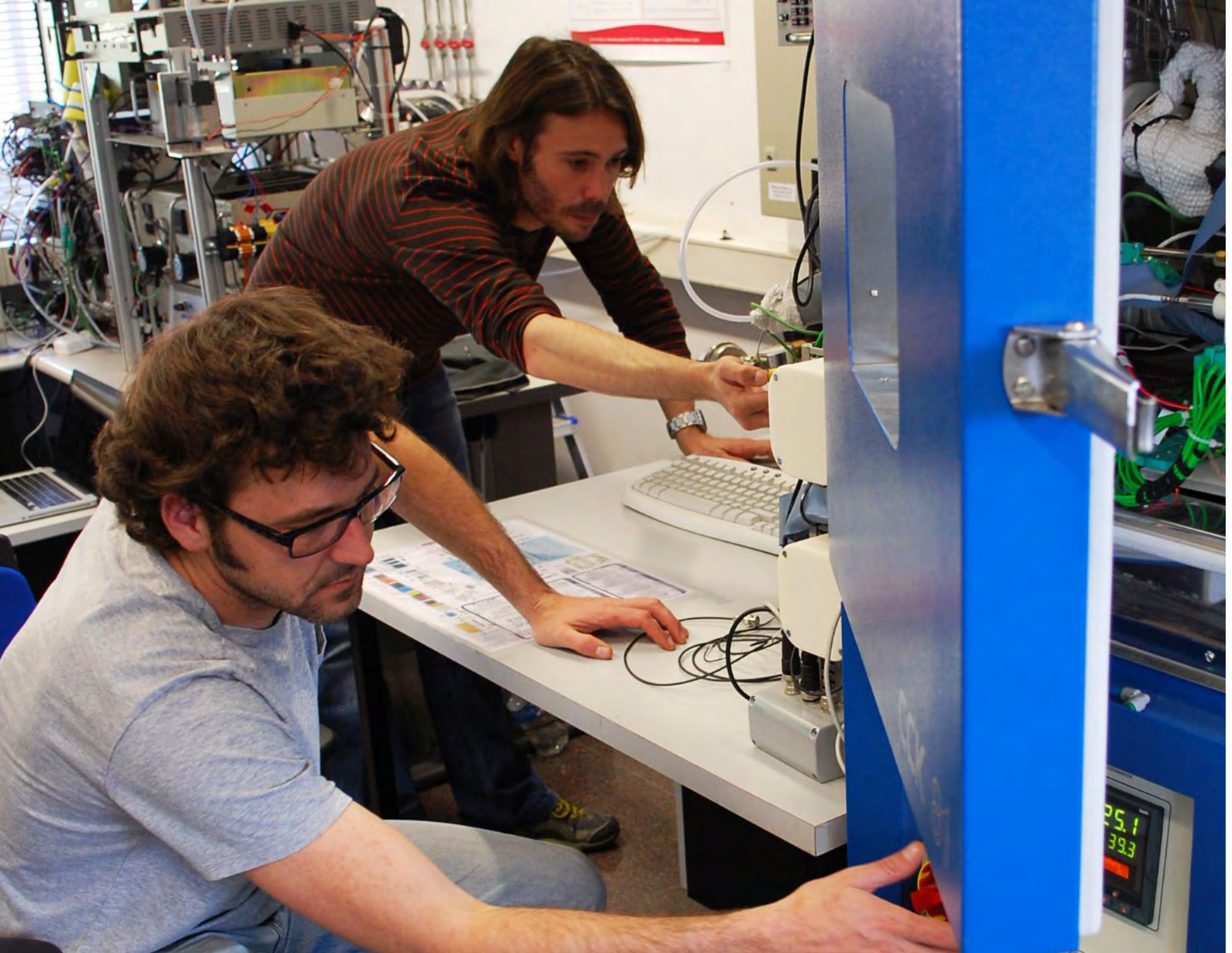
REPORT

2009 2010

Institut de Robòtica
i Informàtica Industrial

CSIC
Consejo Superior de Investigaciones Científicas

UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH



INDEX

Alberto Sanfeliu
Director

In the period 2009-2010, despite its difficulties due to the huge economical crisis in Spain and in Europe, the Institute has accomplished significant outcomes thanks to the enthusiasm of its researchers and of its administration and service staff.

It is important to highlight that in this period, the Institute has secured three new European projects (*GARNICS - Gardening with a cognitive system; CEEDs - The collective experience of emphatic data systems; and IntellAct - Intelligent observation and execution of actions and manipulations*), which increase even more our already strong international collaboration with top research centers in Europe. Moreover, our researchers have also obtained three new national research projects in their areas of expertise (*RobTaskCoop - Robot human task cooperation in urban areas; CUIK++ - An Extension of branch-and-prune techniques for motion analysis and synthesis of complex robotic systems; and DISCPICO - Design and implementation of control systems for PEM fuel cells and their integration into distributed electrical power generation systems*), and six technological transfer projects. With these research activities the Institute has consolidated its research focus in human oriented robotics, an initiative from the period 2007-2008.

Our number of publications has been 40% higher than in the previous biannual period and we have increased by 43% our journal publications in the first quartile of their respective areas for the period 2009-2010. The number of PhD students has also increased by 25% with respect to the period 2007-2008. All this is the result of the commitment of our members in carrying out top quality research that has allowed securing competitive project funds with an economic value of 4.56 million Euros.

In the year 2010, the Institute enlarged its facilities by 232 m^2 in the floor -1. This modest increment in space has allowed us to extend the Workshop and to open three new laboratories, the Mobile Robotics Lab, the Kinematics and Robot Design Lab, and the Water Cycle Control Systems Lab, as well as a new meeting room in floor -1. Furthermore, the Institute has increased its visibility to the society through the dissemination of results from its research projects. For example, the urban robot demonstration of the URUS project in the Barcelona street Passeig de Sant Joan in the Gracia's quarter and our educational projects, such as the participation of our student teams in the CEABOT competition of humanoid robots organized by the *Comité Español de Automática* (the Spanish Committee for Automation) attracted considerable attention of local and national media.
We have also emphasized our presence in institutional digital research repositories for scientific documents such as Digital.CSIC and UPCommons.

We are aware that in the coming years it will be even more difficult to overcome the stringent reductions in state and regional research resources. Anyhow, the institute is committed and encourages its researchers to compete for funds at the top European and national levels; and also, to augment its technological transfer to companies, which are the motor for the generation of economic wealth and work positions.

1

OVERVIEW

Description

The *Institut de Robòtica i Informàtica Industrial* is a Joint University Research Institute of the Technical University of Catalonia (UPC) and the Spanish Council for Scientific Research (CSIC).

The Institute has three main objectives:

1. To promote fundamental research in Robotics and Applied Informatics.

2. To cooperate with the community in industrial technological projects.

3. To offer scientific education through graduate courses.

ORGANIZATION

- **Director:** *Alberto Sanfeliu*
  - **Vice-Director:** *Juan Andrade*
  - **Division Head:** *Guillem Alenyà*
  - **Administrative Officer:** *Ana Canales*
- **PhD Members Representative:** *Carlos Ocampo*
- **PhD Students Representative:** *Júlia Borràs*
- **Support Personnel Representative:** *José Lázaro*

The Institute was created in November 1995 as a Joint Research Center of CSIC and UPC. Its current premises are located in the *Parc Tecnològic de Barcelona*, in the Faculty of Mathematics and Statistics building in the South Campus of UPC.

OVERVIEW >

IRI in numbers

In 2009-2010 we worked in 25 research projects with an economic value of 4,562 millions of Euros

see page 20

Our research staff has nearly doubled in size in the last five years:

The number of scientific publications in 2009-2010 was 169, 40 % higher than in 2007-2008

see page 58

In this period, our publications in top journals (1st quartile in their respective scientific areas) was 20, increasing by 43 %

see page 58

4 PhD theses were presented in 2009-2010 and 38 are under development in 2011

see page 68

In 2009-2010 we carried out 6 technology transfer contracts

see page 72

OVERVIEW >

Facilities and services

The Institute hosts 6 laboratories that provide hands on support to the various research activities. Four of these laboratories are devoted to build and test human-centered robotics systems of all kind, including indoor challenging robotics applications, novel parallel mechanisms, and outdoor mobile robotic systems. The other two laboratories help the research activities in automatic control for energy management and fuel cells research.

Complementary services include a mechatronics workshop, TIC services, and overall administrative support.

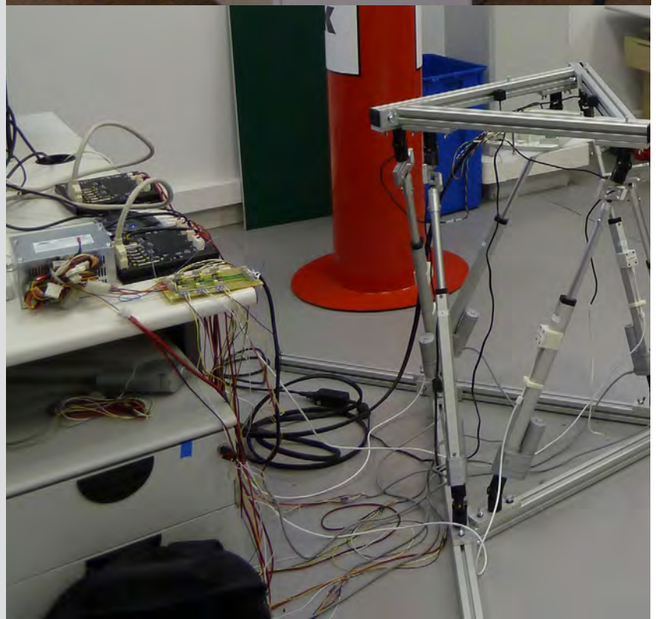
LABORATORIES

Peception and Manipulation Laboratory
Kinematics and Robot Design Laboratory
Mobile Robotics Laboratory
Barcelona Robot Laboratory
Fuel Cell Control Laboratory
Water-cycle Control Systems Laboratory

>Laboratories staff

4

Miguel Allué
Silvia García
Vanessa García
Sergi Hernández

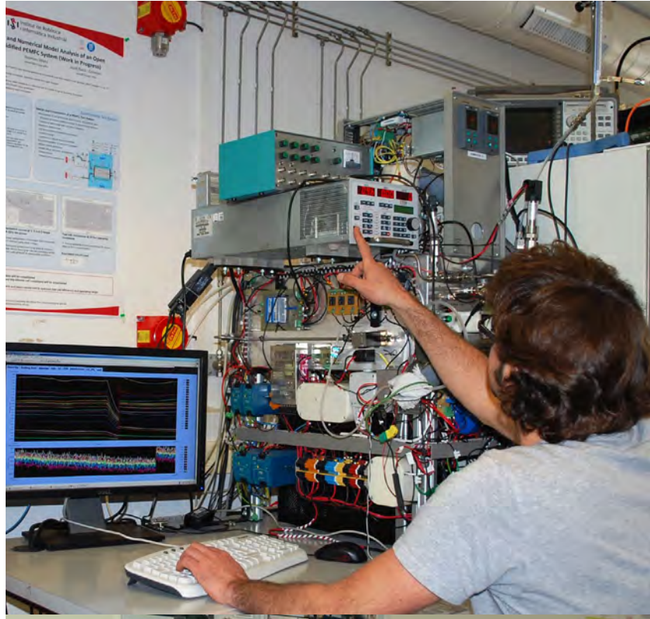


Perception and Manipulation Laboratory
The Perception and Manipulation Laboratory is equipped with 2 workcells: one with 2 standard manipulators and an XY positioner, and the other with 2 WAM arms in a reconfigurable arrangement. Additionally, researchers can find a 3 fingered hand, a Delta haptic interface, force sensors, several conventional cameras, and high speed, high resolution, and 3D cameras. Laboratory service offers quick experimental setup, several standardized software tools, and expertise in robot control and perception algorithms. It also hosts the Humanoid Lab initiative, with 15 small humanoid robots.

Kinematics and Robot Design Laboratory
The Kinematics and Robot Design Laboratory was created thanks to the financial support of the VALTEC program, co-financed with FEDER funds, of the Autonomous Goverment of Catalonia. It was initially created to validate the practical interest of our parallel robot designs, but it has rapidly derived into an active lab where the prototypes designed by the researches of the Group of Kinematics and Robot Design are implemented as proofs of concept.

Mobile Robotics Laboratory
The Mobile Robotics Laboratory is an experimental area primarily devoted to hands-on research with mobile robot devices. The lab includes 3 Pioneer platforms, 2 service robots for urban robotics research based on Segway platforms, and a 4-wheel rough outdoor mobile robot, a six-legged LAURON-III walking robot, and a vast number of sensors and cameras.

Barcelona Robot Laboratory
The Barcelona Robot Lab encompasses an outdoor pedestrian area of 10.000 sq m., and is provided with 21 fixed cameras, a set of heterogeneous robots, full coverage of wifi and mica devices, and partial gps coverage. The area has moderate vegetation and intense cast shadows, making computer vision algorithms more than challenging.



Fuel Cell Control Laboratory
The objective of the Laboratory is the validation and testing of control strategies of fuel cell based energy conversion systems. The facilities are equipped with a supervisor system which monitors necessary safety conditions. Each of the five fuel cell test stations is equipped with the necessary sensors and actuators to be able to operate in a safe and automated way, as well as to modify the working conditions that affect a fuel cell (humidity, temperature, flow, etc.).

Water-cycle Control Systems Laboratory
The aim of this laboratory is to test and validate modelling and control developments for dynamic systems associated to the water cycle. Hence, it provides platforms of pressure, flow and level processes, over which it is possible to implement real-time advanced control strategies. This laboratory is also open to offer services to other teams in the research community.

SERVICES

Mechatronics Workshop
IT Services
Administration

Mechatronics Workshop

The Workshop provides support in the design, construction, and maintenance of electric, electronic, and mechanical devices and prototypes for the research projects carried out at IRI. Current rapid prototyping equipment at the Workshop includes CNC machines and a 3D plastic printer.

2

Ferran Cortés
Patrick Grosch

IT Services

The IRI IT service (IRITIC) is responsible for all the computer and communications infrastructure of the Institute, as well as user support. It has a server room properly suited with our rack servers and communications devices. Our network resources include cable networks (Ethernet) and wireless (Wi-Fi).

4

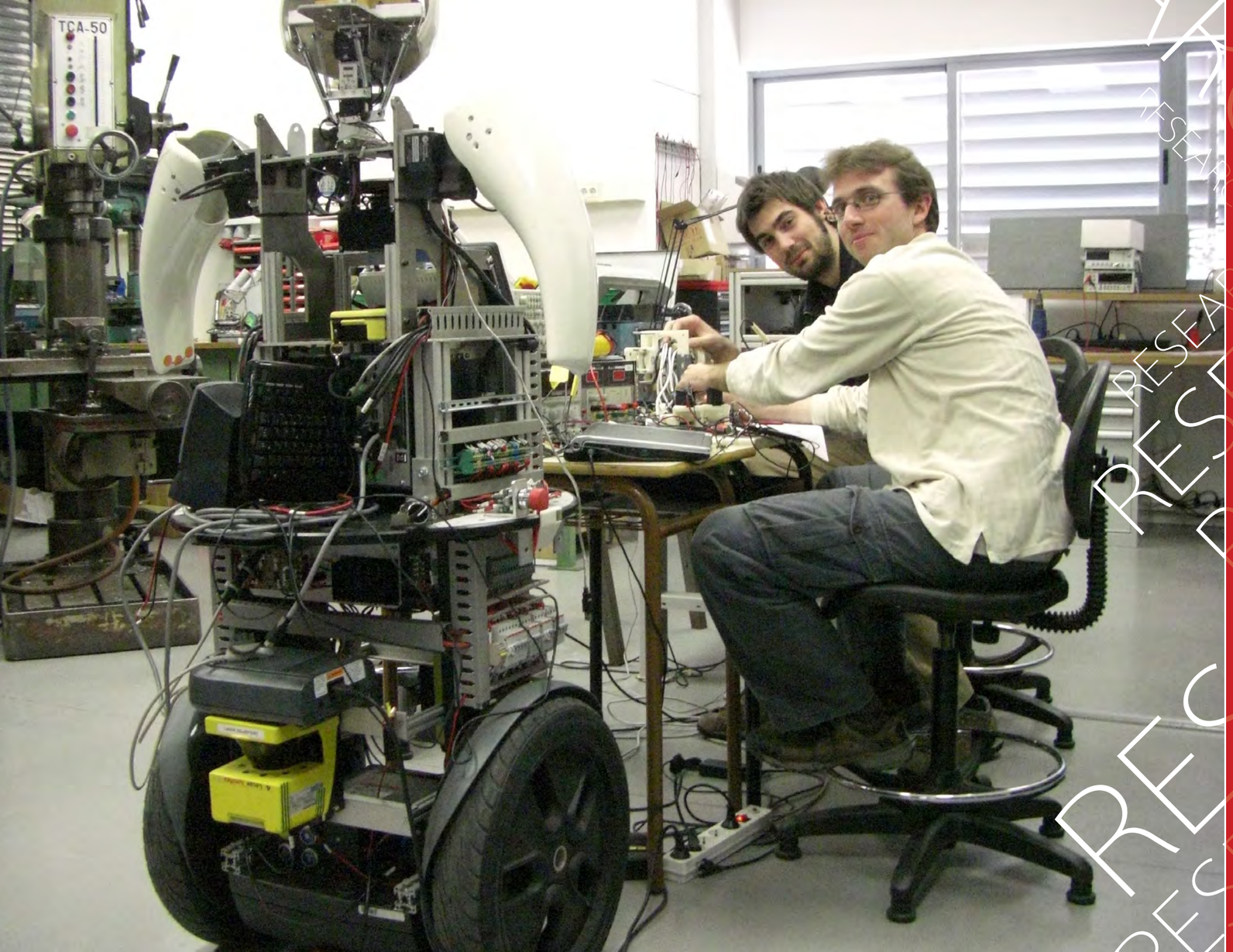
José Lázaro
Evili del Río
José Luis Roncero
Eduardo Wass

Administration

The Institute has the support of an administrative service in charge of all accounting related to projects and contracts as well as the management of the whole Institute's human resources.

7

Ana Canales
Eduardo Ballesteros
Esther Expósito
César González
Eva Llavería
José Luis Rivero
Víctor Vílchez



2

RESEARCH

RESEARCH >

Research projects

IRI's research activities are funded primarily by grants from the EU FP6 and FP7 Research Programme and by competitive funds from the Spanish Ministry of Science and Innovation through its non-oriented fundamental research projects in the DPI program.

Other sources that support our research include projects funded by the Government of Catalonia, by our hosting institutions (CSIC and UPC), and through technology transfer contracts.

> Research projects during 2009 -2010:

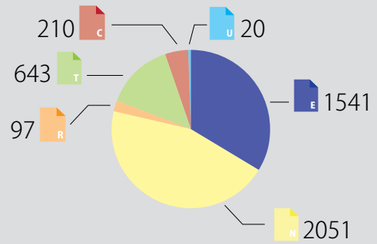
TOTAL: **25**

- E — 5 European Projects
- N — 8 National Projects
- R — 2 Regional Projects
- C — 3 CSIC Projects
- U — 1 UPC Projects
- T — 6 Tech.Transfer Projects

> Project Funds:

in thousand of Euros for projects in 2009 and 2010

TOTAL: **4562**



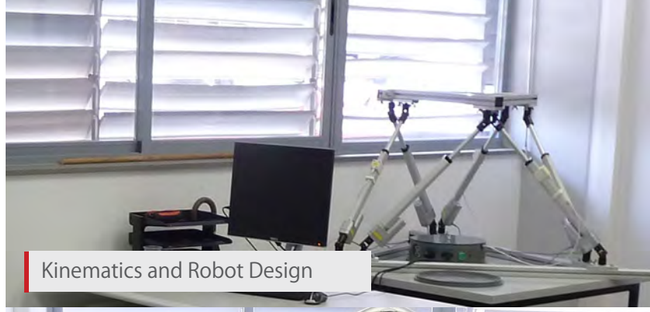
RESEARCH >

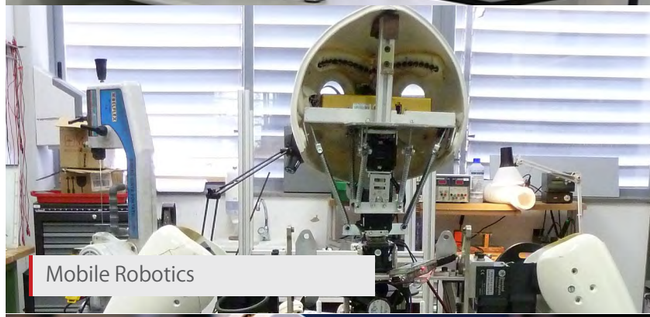
Research lines

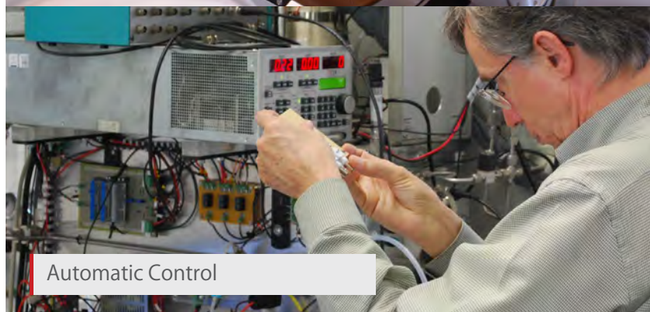
The Institute's research activities are organized in four research lines. Three of them tackle various aspects of robotics research, including indoor and outdoor human-centered human-safe robotics systems, and the design and construction of novel parallel mechanisms. Efforts in the fourth line are aimed at research on energy efficiency, in fuel cells research, and on the management of energy systems.

RESEARCH LINES

- Kinematics and Robot Design
- Mobile Robotics
- Perception and Manipulation
- Automatic Control







RESEARCH >

Kinematics and Robot Design

Federico Thomas
Research head

The Kinematics and Robot Design Group carries out fundamental research on design, construction, and motion analysis of complex mechanisms and structures. In Robotics, these devices are parallel manipulators, multi-fingered hands, reconfigurable mechanisms, or cooperating robots, to name a few, but they appear in other domains too, as mechanistic models of locomotive organisms, molecular compounds, or nano-structures.
During the period 2009-2010, the efforts of the group have been centered on developing theoretical methods for position analysis and singularity characterization of complex multi-loop mechanisms, with an emphasis on both computational and geometrical tools, and on applying such results to the analysis, design and construction of innovative parallel robots. A laboratory of parallel robots has been created to this end.

> Objectives

The group seeks to extend the current knowledge on design of complex articulated systems, and how the motions of such systems can be planned, simulated, and controlled in an efficient and reliable way. Broadening such knowledge is essential for the development of the increasingly-sophisticated devices of today's Robotics, which must be designed to operate within prescribed workspaces, dexterously manipulating objects, and avoiding singular configurations and collisions with the environment all of the time. Efforts focus on developing theories to analyze the behaviour of such systems, and on experimentation with physical constructions of the systems. The group activity organizes around five principal lines: (1) Robot design and construction, (2) Synthesis of linkages, (3) Position analysis of multi-loop linkages, (4) Singularity analysis, and (5) Motion planning.

> Personnel

20

Researchers (8):
Léonard Jaillet
Montserrat Manubens
Josep Maria Mirats
Alba Pérez
Josep Maria Porta
Lluís Ros
Vicente Ruiz de Angulo
Federico Thomas

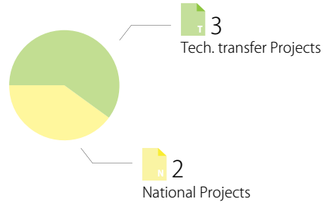
PhD Students (5):
Oriol Bohigas
Júlia Borràs
Anthony Crawford
Nicolás Rojas
Carlos Rosales

Support Staff (2):
Josep Camps
Aleix Rull

Master Students (1)

PFC Students (4)

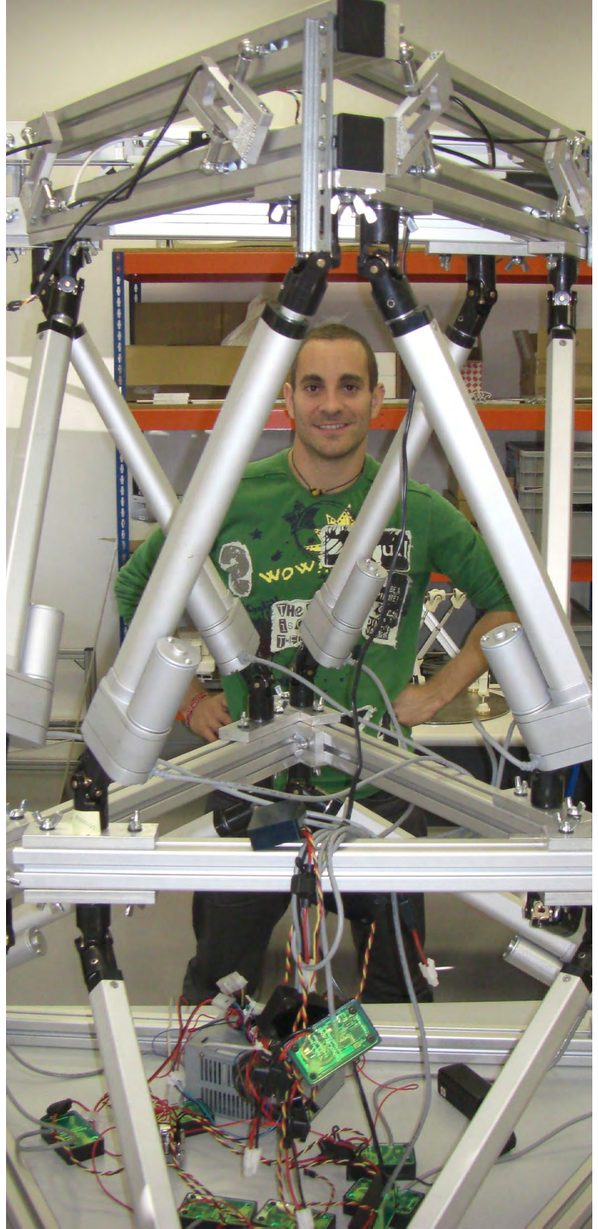
> Project types



Research areas

Robot design and construction
The group designs and constructs innovative mechatronic devices mainly based on parallel architectures. Our developments include the "Wrenchpad" (a six-axis tactile pad), an original air-pumped positioning table, several tensegrity-based robots, a pentaglide, several variations of the Gough-Stewart platform kinematically equivalent the octahedral manipulator, and a twelve degree-of-freedom ameba-like robot.

Singularity analysis
Singularities play a prominent role on understanding of a robot's configuration space. Depending on their nature, singularities give rise to dexterity or controllability losses and thus are to be avoided during the normal operation of a robot. They may, however, give rise to mechanical advantage too - i.e., to the transformation of small joint torques into large end-effector forces - which may be beneficial on specific applications. Also, output singularities provide the boundary of the workspace, which is a useful information for the robot designer. As a consequence, the group is developing new geometric tools that allow characterizing and computing the various singularity loci of a manipulator, either for classes of parallel mechanisms, or for general multi-body systems.



Position analysis of multi-loop linkages
The group develops techniques for linkage position analysis, i.e., for computing all possible configurations that a linkage can adopt, while respecting the kinematic constraints imposed by its joints. The problem finds applications to robotics (direct and inverse kinematics of serial/parallel robots, cooperative manipulation, and closed-chain motion planning), structural biology (conformational analysis of biomolecules), multibody dynamics (initial position and finite displacement problems), and computer-aided design (variational CAD and assembly positioning). The group works essentially along two different approaches, one based on relaxation techniques (see the CUIK project), and the other based on the deduction of characteristic polynomials using Distance Geometry.

Synthesis of Linkages
The group also works on solving dimensional synthesis problems for spatial linkages, in particular targeting rigid-body guidance for finite positions, trajectories and higher-dimensional workspaces. Different approaches are being explored to attack previously unsolved synthesis problems, mainly using Clifford algebras and focusing on solvability issues. The function-to-form problem can be applied in the design and identification of complex articulated systems.

Motion planning
The group also develops methods for closed-chain motion planning. In Robotics, for instance, this problem appears in motion planning for parallel manipulators, in object manipulation with anthropomorphic hands, in constraint-based object positioning, or in surgery or humanoid robots. The problem also appears in Biochemistry, when searching for low-energy paths between different molecular conformations. In all cases, a number of loop-closure constraints give rise to a configuration space of a complex structure on which standard algorithms for motion planning cannot be directly applied. The group addresses this problem using higher-dimensional continuation methods that allow characterizing the configuration space in an incremental way.

Research projects

CUIK+

Analysis and motion planning of complex robotic systems

> Principal Investigator: *Lluís Ros*

The main result of this project has been an efficient algorithm for isolating the configuration space of lower-pair linkages of any structure. The algorithm can handle planar, spherical, or spatial linkages of mobility up to two, and has been tested successfully on difficult problems of Robotics (the position analysis of the most general serial and parallel manipulators, and of complex mechanisms with a large number of interconnected loops) and in Structural Biology (the conformational analysis of highly-constrained biomolecules). The resulting software package - called CUIK - can be run on single- or multi-processor machines, and has been made available to the Scientific Community under the GNU General Public License. The current version has been executed successfully on the Mare-Nostrum supercomputer of the National Supercomputing Center of Barcelona, on experiments that have provided complete maps of the motions of various robots and molecules for the first time.

VALTEC

System of reconfigurable parallel robots

> Principal Investigator: *Federico Thomas*

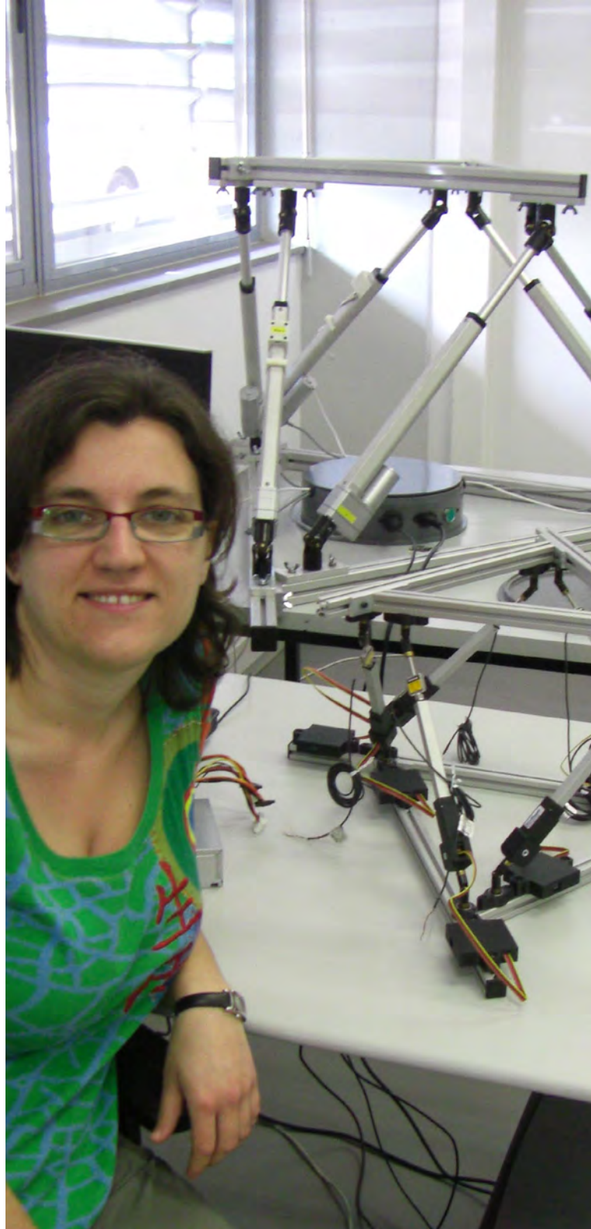
The aim of this project is to provide versatile parallel robots, which can be easily reconfigured for specific tasks, at a low cost. The designed robots are fully sensorized to make them easy to calibrate and operate. They incorporate high resolution inclinometers, tension-compression sensors, and gyroscopes. The information that all of these sensors provide permit to automatically recalibrate the designed robots after a reconfiguration, detect and compensate systematic errors, disambiguate between assembly modes, avoid singularities, detect leg collisions and, in general, any malfunction that might damage the robot.

MANIPTENS

Study, design and implementation of an overactuated manipulator based on tensegrity structures

> Principal Investigator: *Josep Maria Mirats*

The objective of this project is to explore the use of tensegrity structures as a new approach to the construction of mobile robots with different shapes and properties which usual robots, wheeled or legged, do not have. Tensegrity structures are light, deformable structures that may be able to adapt their form to unconstrained environments.



2011
PROJECT

CUIK++

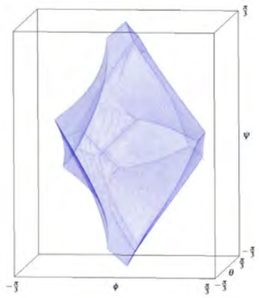
An Extension of Branch-and-Prune Techniques for Motion Analysis and Synthesis of Complex Robotic Systems

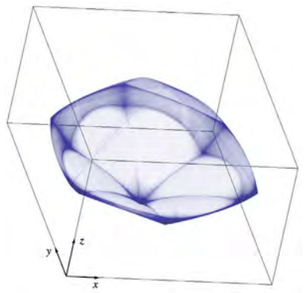
> Principal Investigator: *Lluís Ros*

A main goal of this project is to provide general and complete algorithms for singularity analysis, workspace determination, and dimensional synthesis on multi-body systems of general structure. This will be done by complementing the results of the precedent CUIK+ project with new techniques for critical set computation, higher-dimensional continuation, and randomized exploration. The project also seeks to implement these algorithms efficiently into a new software platform able to perform integral motion analysis and synthesis of complex multi-body systems. In order to obtain solutions in practical times even for complex problems, the platform will be enabled to run on multi-processor machines, and to exploit the possibility of distributing the operations on highly-parallel processing units. A final goal is to demonstrate the usefulness of the platform on complex problems of Robotics, such as grasp synthesis for anthropomorphic hands.

National PROJECT N — 91K €

jan2011 — dec2013





IDAHO

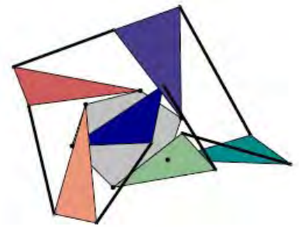
Kinematic synthesis for a scalable finger/thumb exoskeleton robot

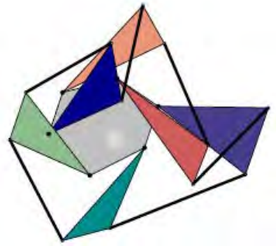
> Principal Investigator: *Alba Pérez*

This project is a subaward from a University of Idaho/University of California, Irvine NIH grant. The goal is to design an exoskeleton-like robotic device to assist in tasks of finger and thumb rehabilitation. The exoskeleton will be designed using visual hand data as input. The mechanisms corresponding to fingers and thumb have different structure: for the finger, a simpler one-degree- of-freedom closed linkage is the preliminary candidate, while for the thumb the robot is expected to have complex spatial motion, accomplished through an overconstrained linkage. In addition to the dimensional kinematic synthesis, the solution is to be optimized based on a series of constraints for size, space occupation, and mechanical advantage, among others.

Tech. transfer CONTRACT T — 8,4K €

mar2010 — feb2011





RESEARCH >

Mobile Robotics

Alberto Sanfeliu
Research head

The period 2009-2010 saw several landmark events for the Mobile Robotics line. The success of the EU URUS project, was crowned by demonstrations of our urban service robots Tibi and Dabo in the UPC campus as well as the Gràcia District in Barcelona.

In this period, we also inaugurated the Barcelona Robot Lab. This facility will help us teach our robots to better serve humans, and also understand the rules of engagement humans expect from this type of robots.

Our activities are equally balanced between fundamental research on all aspects of perception and robust navigation for our robotic systems, as well as in systems integration.

> Objectives

The research activities of the Mobile Robotics and Intelligent Systems line are aimed to endow mobile robots and ubiquitous computing devices the necessary skills to aid humans in everyday life activities. These skills range from pure perceptual activities such as tracking, recognition or situation awareness, to motion skills, such as localization, mapping, autonomous navigation, path planning or exploration.

> Personnel

27

Researchers (6):
Renato Alquézar
Josep Amat
Juan Andrade
Enric Celaya
Iván Huerta
Alberto Sanfeliu

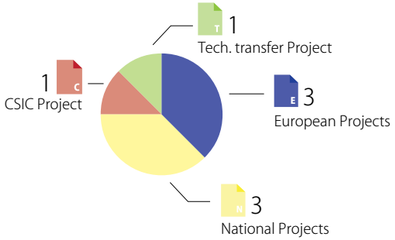
Support Staff (3):
Martí Morta
Joan Pérez
Alberto Sanfeliu

Master Students (3)

PFC Students (1)

PhD Students (14):
Nicolás Amézquita
Andreu Corominas
Gonzalo Ferrer
Anaís Garrell
Edmundo Guerra
Agustín Ortega
Adrián Peñate
Óscar Sandoval
Gerard Sanroma
Eduard Serradell
Ernesto Teniente
Eduard Trulls
Rafael Valencia
Michael Villamizar

> Project types



Research areas

Urban service robotics
The group focuses on the design and development of service mobile robots for human assistance and human robot interaction. This includes research on novel hardware and software solutions to urban robotic services such as surveillance, exploration, cleaning, transportation, human tracking, human assistance and human guiding.

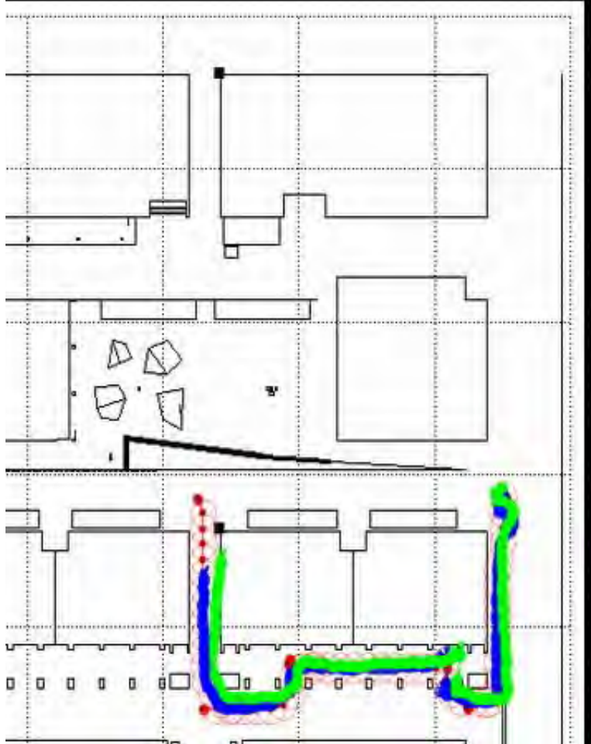
Social robotics
The group's work on social robotics has an emphasis in human robot interaction and collaboration, developing new techniques to predict and learn human behaviors, human-robot task collaboration, and the generation of emphatic robot behaviors using all types of sensors, computer vision techniques and cognitive systems technologies.

Robot localization and robot navigation
This research area tackles the creation of robust single and cooperative, indoor and outdoor robot localization solutions, using multiple sensor modalities such as GPS, computer vision and laser range finding, INS sensors and raw odometry. The area also seeks methods and algorithms for autonomous robot navigation, and robot formation; and the application of these methods on a variety of indoor and outdoor mobile robot platforms..

SLAM and robot exploration
We develop solutions for indoor and outdoor simultaneous localization and mapping using computer vision and three-dimensional range data using Bayesian estimation. The research includes the development of new filtering and smoothing algorithms that limit the load of maps using information theoretic measures; as well as the design and construction of novel sensors for outdoor mapping. This research area also studies methods for autonomous robotic exploration.

Tracking in computer vision
We study the development of robust algorithms for the detection and tracking of human activities in indoor and outdoor areas, with applications to service robotics, surveillance, and human-robot interaction. This includes the development of fixed/moving single camera tracking algorithms as well as detection and tracking methods over large camera sensor networks.

Object recognition
The group also performs research on object detection and object recognition in computer vision. Current research is heavily based on boosting and other machine learning methodologies that make extensive use of multiple view geometry. We also study the development of unique feature and scene descriptors, invariant to changes in illumination, cast shadows, or deformations.



Research projects

CEEDS

The collective experience of empathic data systems

> Leader for IRI: ***Alberto Sanfeliu***

The Collective Experience of Empathic Data Systems (CEEDS) consortium advances a novel integrated technology that supports the experiencing, analyzing and understanding of massive datasets. Key axiom of CEEDS is that discovery is the identification of patterns in complex data sets by the human brain. It is these implicit information processing capabilities that CEEDS seeks to exploit. The implicit cues, as measured through novel sensing systems, including bio-signals and non-verbal behaviour form the core information based on which the CEEDS system will process data and present them to the user(s). Confluence is achieve firstly, through immersion of the user in synthetic reality spaces, that allow to explore complex data spaces following narrative structures of varying spatio-temporal complexity, and secondly, through an unobtrusive multi-modal wearable technology that will provide an assessment of the behavioural, physiological and mental states of the user.

* IRI budget
Total budget: 6,5 M€

URUS

Ubiquitous networking robotics in urban settings

> Principal investigator: ***Alberto Sanfeliu***

In this project we want to analyze and test the idea of incorporating a network of robots (robots, intelligent sensors, devices and communications) in order to improve life quality in urban areas. The URUS project is focused in designing a network of robots that in a cooperative way interact with human beings and the environment for tasks of assistance, transportation of goods, and surveillance in urban areas. Specifically, our objective is to design and develop a cognitive network robot architecture that integrates cooperating urban robots, intelligent sensors, intelligent devices and communications.

* IRI budget
Total budget: 2,6 M€

PAU

Perception and action under uncertainty

> Principal Investigator: ***Juan Andrade***

The goal of this project is to provide a theoretical foundation of the relation between perception and action in the presence of uncertainty. The main outcome of the project will be novel scientific contributions on Bayesian estimation applied to robotics problems with large state spaces. In particular, the project will produce: novel uncertainty parameterizations that allow efficient inference, new probabilistic hypotheses testing strategies with respect to information load, new active exploration paradigms for scene and object model acquisition, and novel pose estimation algorithms.
On the technical side, two demonstration applications are foreseen: manipulation of planar deformable objects and real-time SLAM systems in large outdoor unstructured environments. These two specific robotics applications, although very different in nature share many common aspects with respect to the formalism of the perception, estimation, and exploration algorithms used.

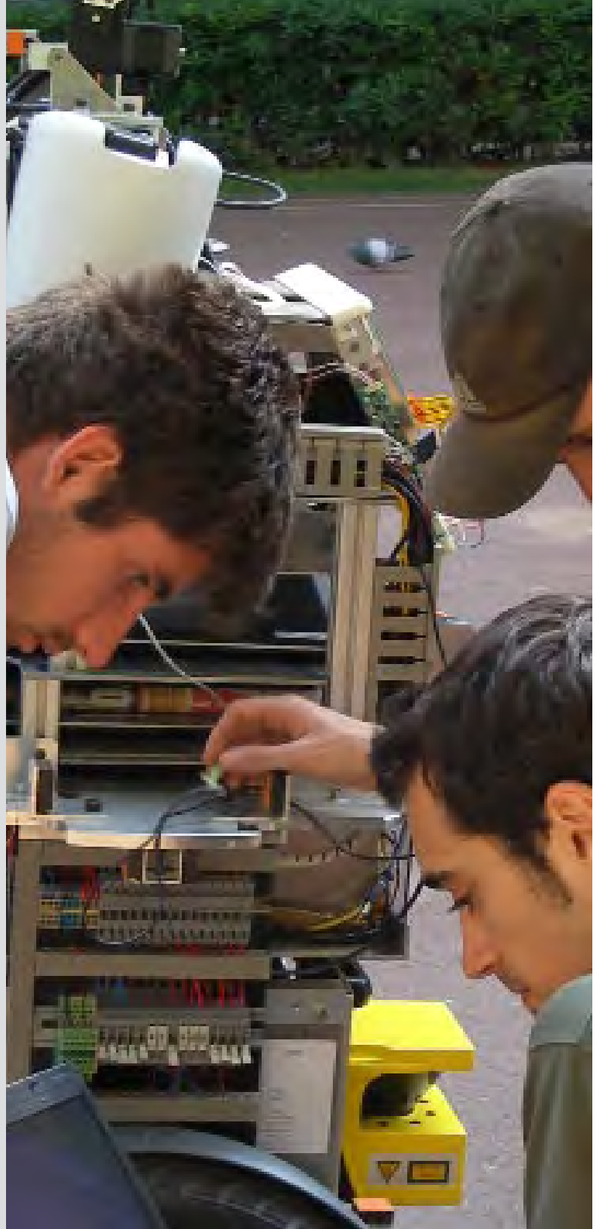
2011
PROJECT

RobTaskCoop

Robot-human cooperation in urban areas

> Principal Investigator: *Alberto Sanfeliu*

The use of robots will be in the near future extended to new demanding applications to help humans in everyday tasks, where cooperative and the friendly interaction with humans will be at the core of the robotic system. In order to achieve this, robots in combination with the environment systems have to incorporate perception systems, such as cameras to detect, identify and track people; social robot communication abilities, such as motion (positioning, adaptability and anticipatory behavior), speech and gesture capabilities; and social robot behaviors, for example guide people from one place to another.
The general objective of this project is to design new techniques of cooperation between robots and human beings for doing tasks in urban environments, using the information obtained from the robot and environment (network cameras) perception systems. Specifically we want to advance in the development of new techniques in: localization and navigation in urban areas in dense urban areas; robot and environment perception (human action detection and tracking) where illuminant conditions can change; learning and adaptation of robot-human interaction; and designing new models for robot-human task cooperation (for example in guiding people).



UbRob

Ubiquitous robotics for urban settings

> Principal Investigator: *Alberto Sanfeliu*

In this project we research and develop techniques in ubiquitous robotics (which implies the cooperation between robots, intelligent systems and communication networks) in order to help humans in urban tasks, specifically in the area of assistance and guidance of people. We have identified a set of research topics in order to apply ubiquitous robotics in urban settings: localization and navigation of robots; updating dynamic maps; environment perception; human-robot interaction; task planning; and communication networks.

CONET

Cooperating Objects Network of Excellence

> Principal Investigator: *Alberto Sanfeliu*

EU-funded network of excellence building a strong community in the area of Cooperating Objects including research, public sector and industry partners from the areas of embedded systems, pervasive computing and wireless sensor networks.

AIN-IRI

Obstacle avoidance for UAVs using computer vision

> Principal Investigator: *Juan Andrade*

In this project we developed techniques to compute time to collision measures for the autonomous guidance of unmanned aerial vehicles. The project goal was to analyze video signals using state of the art computer vision techniques.

EARMU

Active exploration for urban mobile robots

> Principal Investigator: *Juan Andrade*

This project addresses Bayesian estimation for large state spaces, including active exploration and simultaneous localization and mapping in outdoor urban settings.

RESEARCH >

Perception and Manipulation

Carme Torras
Research head

Research focuses on enhancing the perception, learning, and planning capabilities of robots to achieve higher degrees of autonomy and user-friendliness during everyday manipulation tasks in domestic, service and industrial environments. Some topics addressed are the geometric interpretation of perceptual information, construction of 3D object models, action selection and planning, reinforcement learning, and teaching by demonstration

>Objectives

Domestic, service and industrial robotics require the easy acquisition of 3D object models and user-friendly programming of manipulation tasks. The efforts of our group are oriented toward:
- 3D active perception combining several sensory modalities, such as color vision, depth from time-of-flight, structured light, stereo, and haptics;
- Teaching manipulation skills to a robot under a learning by demonstration approach, as well as teaching the robot to accomplish tasks requiring planning through rule learning; with
- Special attention to the perception and manipulation of deformable objects, such as plants and cloth.

>Personnel

18

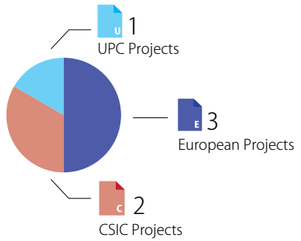
Researchers (7):
Maria Alberich
Guillem Alenyà
Babette Dellen
Pablo Jiménez
Francesc Moreno
Arnau Ramisa
Carme Torras

PhD Students (5):
Alejandro Agostini
Adrià Colomé
Sergi Foix
Pol Monsó
Leonel Rozo

Master Students (1)

PFC Students (5)

>Project types



Research areas

Learning by demonstration
Learning object-action relations to accomplish tasks at different levels of abstraction, where object models are generated from visual and depth information, and actions, involving manipulation skills, are learned from demonstrations provided by a human using multimodal algorithms that combine vision and haptics.

Planning for perception and manipulation
We are interested in planning algorithms for object modeling, with special interest in deformable objects. High-level task formulations will be integrated with low-level geometry-based methods and simplified physical models, as well as with an on-line sensory-based treatment of uncertainty so as to come up with a specified sequence of motion commands.

Shape recovering of deformable objects
To develop non-iterative solutions to recover the shape of the deformable objects. This is a severely under-constrained problem and many different kinds of prior models have been introduced to restrict the space of possible shapes to a manageable size.

Projective geometry applied to robotics
The objective is to exploit projective geometry results to acquire object/scene models and camera motion with uncalibrated cameras. Our results have been applied to estimation of epipolar geometry, depth from zoom and time to contact computation.

Research projects

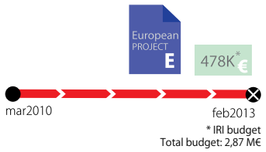
GARNICS

Gardening with a cognitive system

> Leader for IRI: *Carme Torras*

The GARNICS project aims at 3D sensing of plant growth and building perceptual representations for learning the links to actions of a robot gardener. Plants are complex, self-changing systems with increasing complexity over time. Actions performed at plants (like watering), will have strongly delayed effects. Thus, monitoring and controlling plants is a difficult perception-action problem requiring advanced predictive cognitive properties, which so far can only be provided by experienced human gardeners. Sensing and control of a plants actual properties, i.e. its phenotype, is relevant to e.g. seed production and plant breeders.

We address plant sensing and control by combining active vision with appropriate perceptual representations, which are essential for cognitive interactions. Core ingredients for these representations are channel representations, dynamic graphs and cause-effect couples (CECs).

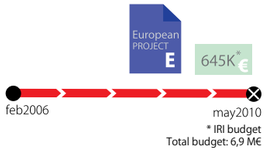


PACO-PLUS

Perception, action & cognition through learning of object-action complexes.

> Leaders for IRI: *Carme Torras and Juan Andrade*

PACO-PLUS is an integrated Project funded by the European Commission through its Cognition Unit under the Information Society Technologies of the sixth Framework Programme (FP6). PACO-PLUS brings together an interdisciplinary research team to design and build cognitive robots capable of developing perceptual, behavioral and cognitive categories that can be used, communicated and shared with other humans and artificial agents. To demonstrate our approach we are building robot systems that will display increasingly advanced cognitive capabilities over the course of the program. They will learn to operate in the real world and to interact and communicate with humans. To do this they must model and reflectively reason about their perceptions and actions in order to learn, act and react appropriately.



APREN

Perceptual models and learning techniques for service robots

> Principal Investigator: *Carme Torras*

Several learning algorithms will be adapted to a robot manipulator setting, with particular emphasis on learning by demonstration, supervised and reinforcement learning. These algorithms will be integrated with perception systems and robot manipulators available at IRI. Multi-modal perception is often required for learning manipulation skills by demonstration and, therefore, it is essential to integrate the data coming from vision, ToF sensors and haptic displays into the learning schemes.

2011
PROJECT

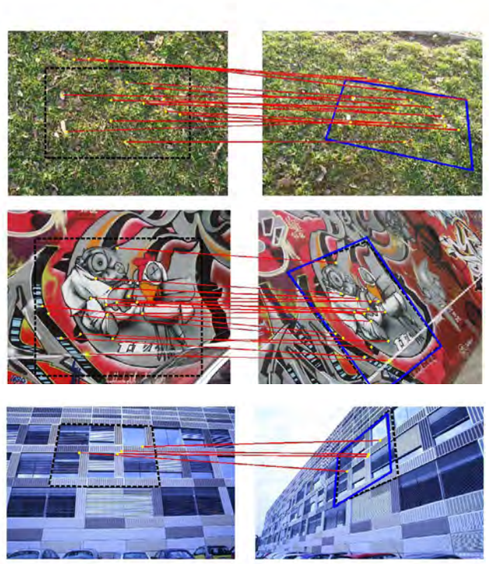
IntellAct

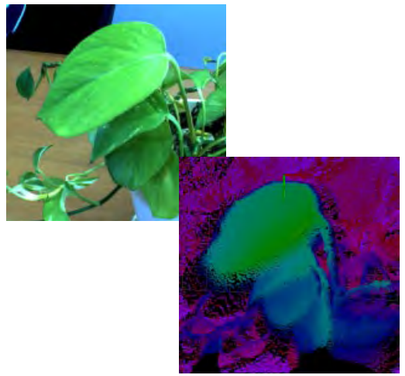
Intelligent observation and execution of Actions and manipulations

> Leader for IRI: *Carme Torras*

IntellAct addresses the problem of understanding and exploiting the meaning (semantics) of manipulations in terms of objects, actions and their consequences for reproducing human actions with machines. It comprises three building blocks: Learning, Monitoring, and Execution.
The analysis of low-level observation data for semantic content (Learning) and the synthesis of concrete behavior (Execution) constitute the major scientific challenge of IntellAct. Based on the semantic interpretation and description and enhanced with low-level trajectory data for grounding, two major application areas are addressed by IntellAct: the monitoring of human manipulations for correctness and the efficient teaching of cognitive robots for manipulation. To achieve these goals, IntellAct brings together recent methods for (1) parsing scenes into spatio-temporal graphs and so called 'semantic event chains', (2) probabilistic models of objects and their manipulation, (3) probabilistic rule learning, and (4) dynamic motion primitives for trainable and flexible descriptions of robotic motor behavior.

* IRI budget
Total budget: 2,96 M€





BPnP

Pose Priors for Simultaneously Solving Alignment and Correspondence

> Principal Investigator: *Francesc Moreno*

Estimating camera pose given a set of 3D-object and 2D-image feature points is a well understood problem when correspondences are given. However, when such correspondences cannot be established a priori, one must simultaneously compute them along with the pose. Most current approaches to solving this problem are too computationally intensive to be practical. In the BPnP project we explored algorithms to overcome this limitation by taking advantage of the fact that, in practice, some prior on the camera pose is often available. For instance, if we seek to retrieve the pose of a camera observing a building we can exploit the fact that the camera must be pointing towards the building and be above ground level. In this project we developed mathematical and probabilistic models that allowed and efficient integration of this kind of information. The results were applied to various problems camera pose estimation, both in rigid and deformable environments.

Humanoid Lab

The humanoid laboratory

> Principal Investigator: *Guillem Alenyà*

This project is mainly addressed to students interested in learning basic concepts of robotics. Hosted at *Institut de Robòtica i Informàtica industrial*, our goal is to introduce engineering and mathematics students to the robotics world.
Our philosophy: Learning, Technology and Openess.

RESEARCH >

Automatic Control

Maria Serra
Research head

The Automatic Control line develops basic and applied research in automatic control theory, with special emphasis on modeling, supervision and control of nonlinear, complex and/or large-scale systems. The group has acquired specific expertise in the application of advanced control techniques to environmental resources management, specifically in the water and energy fields. The research is oriented towards improving the efficiency in real-time industrial processes, such as power generation systems, water supply and distribution networks, urban drainage, power supply grids, among others.
The group takes part in European knowledge networks and also offers training in modeling of dynamical systems and advanced automatic control for undergraduate, MSc and PhD students from UPC also also from other universities and research centers worldwide.

> Objectives

The main objectives of the research developed by this line can be summarized as follows:
- Contribution to the development of new methodologies of modeling, supervision and control of complex dynamical and large-scale systems;
- Contribution to improving the efficiency of industrial processes related to the fields of water and energy;
- Implementation of the proposed methodologies and designs in real dynamic systems; and
- Training of research staff and students in the field of automatic control.

> Personnel

25

Researchers (6):
Gabriela Cembrano
Cristian Kunusch
Carlos Ocampo-Martínez
Vicenç Puig
Jordi Riera
Maria Serra

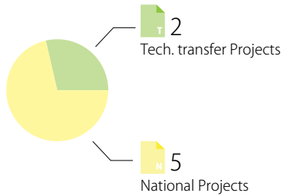
PhD Students (9):
Salvador De Lira
Juan Manuel Grosso
Attila Husar
Valeria Javalera
Bernat Joseph
Maria Laura Sarmiento
Stephan Strahl

Master Students (6)

PFC Students (2)

Support Staff (2):
Tom Creemers
Albert Rosich

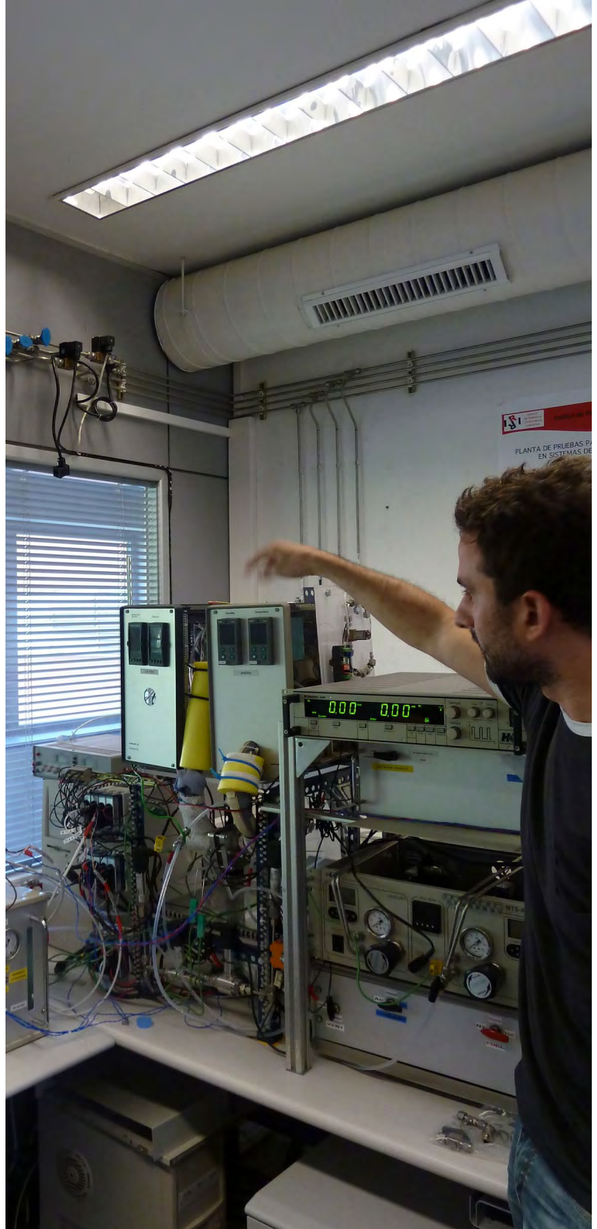
> Project types



Research areas

Modelling and control of complex nonlinear systems
In order to design controllers for complex nonlinear systems, it is fundamental to have mathematical models of the systems' dynamic behaviour. Regarding dynamic modelling of complex nonlinear systems, the Control Group focuses on four subjects: models for multi-domain systems using PHS formulation; distributed parameter models and their order reduction; experimental characterisation techniques combining the use of time and frequency responses of the dynamic system, conceived as diagnosis tools; the design of observers to be integrated in the control systems in order to improve the system performance and minimise the number of sensors. Regarding control system design, the work is based on the following advanced control techniques: passivity-based control, Optimal Control, Model Predictive Control, Variable Structure Control (VSC) and Linear Parameter Varying (LPV)-Robust Control.

Modelling and control of large-scale networked systems
In automation, it is more and more frequent to deal with large scale networked systems which are composed by a multitude of elements of diverse dynamical nature. Obtaining a mathematical model oriented to the management and control of such systems should take into account their real time operation and complex topology. Moreover, complementary considerations such as physical constraints, hybrid behaviour and bounded disturbances are also challenging topics in the study of this kind of systems.



Real-time Supervisory Control, Fault Diagnosis and Fault-Tolerance
Reliability is a feature required in modern control systems which implies the introduction of fault diagnosis and fault tolerant control modules that allow to know in real-time if there is any non-desired behaviour (fault) and activate some remedial action in order to keep the system in operation (fault tolerance). Complementary aspects as sensor/actuator location for achieving the desired fault diagnosis and tolerance are also addressed.

Design and implementation of decision-support tools for resources management systems with multiple, heterogeneous constraints
A large variety of real-time resource allocation problems dealing with long- and medium-term resources management typically appear in public services and industry. Some examples are water management (both surface and pipeline systems), energy generation and distribution, and environmental planning. The operation of these systems requires dealing with multiple, heterogeneous constraints. Not just physical constraints are to be met, but also those imposed by regulations, operational practices, economy, ecology, etc. The overall aim is to step away from the classical trial-and-error-based simulation approach and create real problem-solving tools for optimal management of large-scale resources management problems.

Applied Research
Theoretical knowledge is applied in real cases, in close collaboration with industry. Currently, research is mainly focused on four fields: modelling and control of systems based on Proton Exchange Membrane Fuel Cells based systems; modelling, control and management of electrical networks; design of optimal operational management of networked systems related to the urban water cycle and sensor data validation/reconstruction of instrumentation systems. The Control Group gives primary importance to the tasks of implementation and experimental validation of the proposed control and modelling methodologies. These final stages of the control design process are developed either in the industry or at the Institute's Laboratories: the Fuel Cells Laboratory and the Water Cycle Control Systems Lab.

Research projects

WATMAN

Analysis and Design of distributed optimal control strategies applied to large-scale WATer systems MANagement

> Principal Investigator: *Gabriela Cembrano*

The WATMAN Project deals with the global management of the hydric networks related to the UWC (called in the sequel UWC-related networks or simply UWC networks). It should be pointed out that this management not only comprises the design of control strategies to fulfill performance objectives but also includes the development of a control-oriented modeling for the UWC networks, regardless of their nature (raw-water, drinking water or sewage).

Additionally, system disturbances, which are present in all engineering systems, must be taken into account. In the case of water systems, stochastic disturbances associated to water demand and rain predictions (for sewage network) are important examples thereof. The influence of those disturbances over the UWC networks, their nature and modelling approaches belong to the set of research topics to be treated within the project.

DICOPEM

Advances in the modeling and design of controlers for PEM fuel cells based systems

> Principal Investigator: *Jordi Riera*

This project is focused on modeling and control design for PEM fuel cells based systems. First of all, detailed models of the strongly nonlinear phenomena that occur in the interior of the fuel cells are obtained. Special attention is given to the humidification and diffusion phenomena.A dynamic thermal and water distribution model of an open cathode proton exchange membrane fuel cell is developed and validated through experimental tests. The Port Hamiltonian Systems (PHS)formalism, an approach that allows to tackle the different nature phenomena in an unified way, is also studied to emphasize the energy aspects.It is also an objective of the project to obtain reduced models that preserve the PHS structure.These models, that are used to design controllers, must integrate all the subsystems that compose a PEM fuel cell based generation system.The second major objective of the project is to design and implement nonlinear controllers for PEM fuel cells based systems.

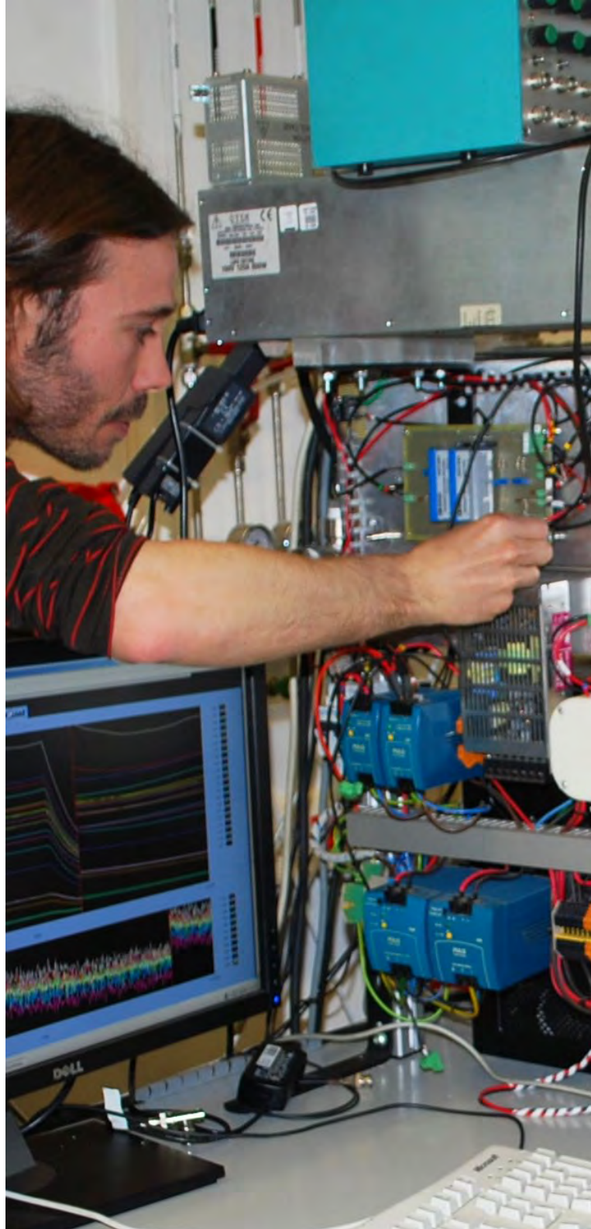
ELISSA-CRISALIDA

Supervisory Algorithms for Safe and Efficient Energy Distribution

> Principal Investigator: *Jordi Riera*

The ELISSA project develops new algorithms for intelligent energy routing on large distribution networks. The project seeks to determine through which paths should the energy flow on such networks, in order to avoid line overloads and resource conflicts, minimizing operational costs and blackout risks at the same time. The project will provide tools for safe reconfiguration and after-blackout recovery of such networks, based on the constraint programming paradigm.

The project is made in collaboration with SITEL S.A., within the framework of the larger CRISALIDA Project, funded by the Spanish Ministry of Education and Science through the CENIT Programme 2008-2010. The project consortium involves 15 industrial partners and 17 research institutions from all over Spain.



2011
PROJECT

DISCPICO

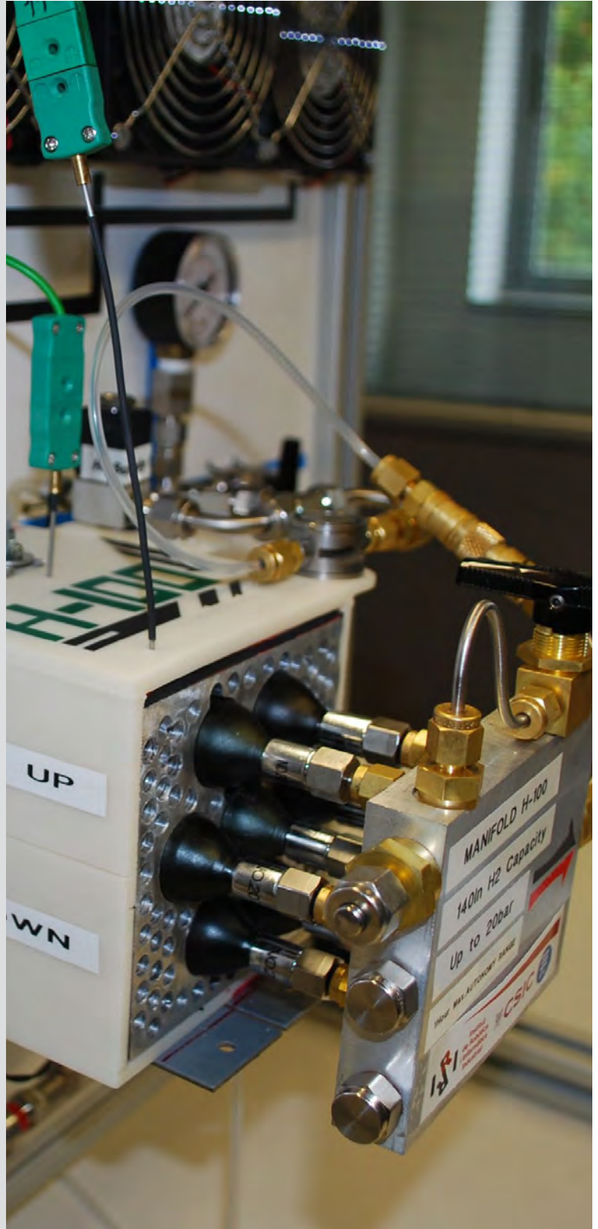
Design and implementation of control systems for PEM fuel cells and their integration into distributed electrical power generation systems

> Principal Investigator: *Maria Serra*

This project is focused on Protonic Exchange Membrane Fuel Cells (PEMFC). The aim of the project is twofold: to improve the PEMFC systems performance and to take full advantage of PEMFC integration into Distributed Electrical Generation Systems (DEGS). The project results will contribute to the definition of an integrated hydrogen based energy system, which has been seen as a possible scenario for future energy supply in Europe. The project objectives are the design, implementation and comparative analysis of controllers for PEMFC systems on one hand, and on the other hand, the energy management and supervisory control that permits the efficiency enhancement of Distibuted Electrical Generation Systems by means of hydrogen and PEM fuel cell technologies. Despite the great interest of the research comunity in PEMFC modeling and control, the controllers described in the open literature still have to be improved and some problems remain unsolved.

National PROJECT N — 10K €

jan2011 — dec2011



ITACA

Integration of advanced techniques of modelling, control and supervision applied to the water-cycle management

> Principal Investigator: *Gabriela Cembrano*

This project proposal deals with the contribution of advanced modelling, control and supervision techniques to improve the management of hydraulic systems involved in the urban water cycle. This cycle is comprised of the drinking water supply, delivery and distribution as well as the urban drainage system, which collects sewage and rainwater and renders it back to the receiving environment, in general, after an appropriate treatment. The proposal involves developing mathematical models of hydraulic dynamic systems in the urban water cycle by using new hybrid systems techniques, as well as the design and implementation of predictive controllers to compute, ahead in time, the control policies and strategies which contribute to optimize: allocation of limited water resources; quality of service to users; avoidance of flooding due to rainwater exceeding urban drainage capacity; and avoidance of polluting discharges to the receiving waters in urban drainage, among many others.
The computation and implementation of the control strategies is associated to the use of telemetry and telecontrol systems. Demonstrators of the achievable benefits will be developed, based on real cases supplied by the collaborating companies

National PROJECT N — 106K €

oct2006 — dec2009

CETAQUA

Promotion and supervision of research projects related to efficiency in water networks

> Principal Investigator: *Gabriela Cembrano*

The collaborative project between IRI and CETaqua, a research center created in 2006 and cofounded by CSIC, UPC and Agbar; seeks to develop applied research projects with the water industry, focused on the use of automatic control techniques to improve the efficiency in water systems, including water resources management, drinking water networks, urban drainage and treatment plants.

Tech. transfer CONTRACT T — 180K €

jun2007 — jun2011

ACHEG

Advanced controllers for new hybrid electrical generation systems based in PEM fuel cells

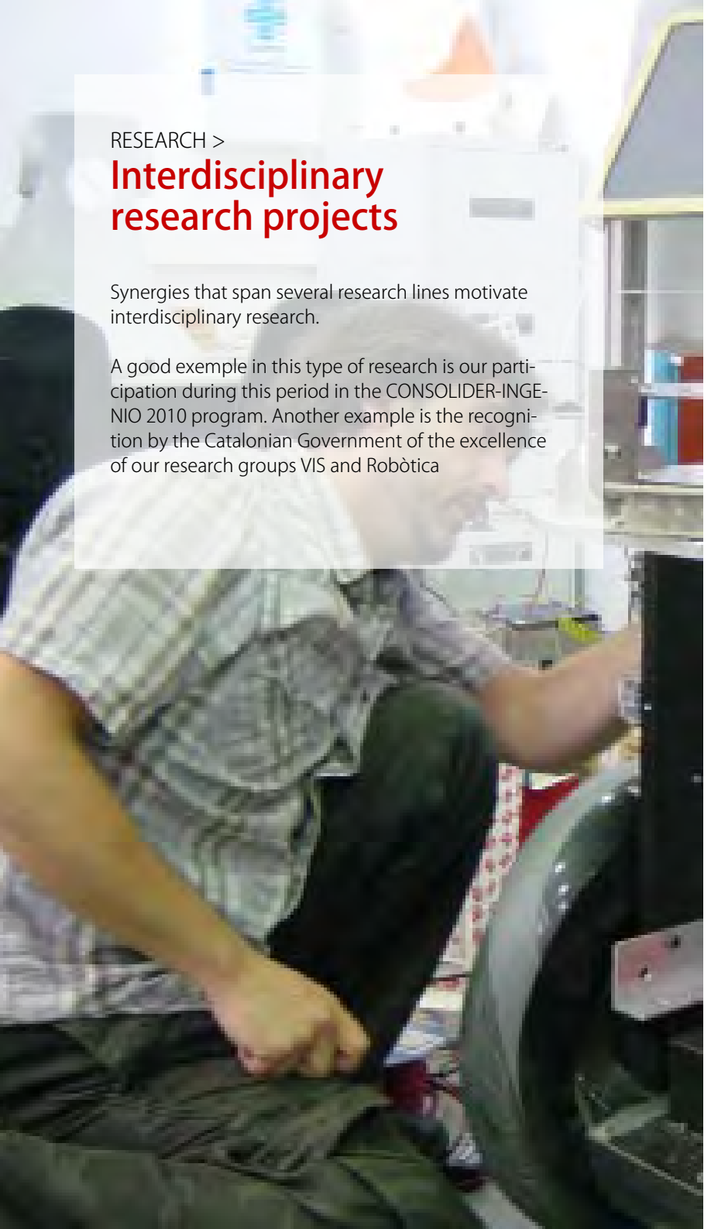
> Principal Investigator: *Jordi Riera*

Upcoming sustainable power systems should incorporate efficient energy converters, such as fuel cells, and electrical storage as supercapacitors or batteries. These systems, known as Hybrid Electrical Generation Systems (HEGS), include many subsystems with different dynamics and constraints, but the whole system must work in a coordinated and efficient way. This project tries to solve some of the problems in autonomous HEGS by proposing accurate models and new advanced controllers for the Fuel cell subsystem and efficient Energy Management Strategies to improve the energy fluxes between subsystems.

National PROJECT* N — 9,7K €

jan2010 — mar2011

* Founded by the National Agency AECID but participated by international members



RESEARCH >

Interdisciplinary research projects

Synergies that span several research lines motivate interdisciplinary research.

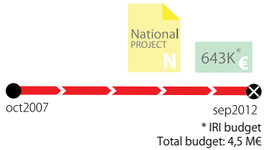
A good exemple in this type of research is our participation during this period in the CONSOLIDER-INGENIO 2010 program. Another example is the recognition by the Catalonian Government of the excellence of our research groups VIS and Robòtica

MIPRCV

CONSOLIDER-INGENIO 2010 Multimodal interaction in pattern recognition and computer vision

> Leader from IRI: *Alberto Sanfeliu*

Social and industrial demands for Multimodal Interactive (MI) technologies and advanced man-machine interfaces are increasing dramatically. Pattern Recognition (PR) and Computer Vision (CV) play a highly relevant role of in the development of these MI technologies and interfaces. However, traditional PR and CV technologies have mainly focused on full automation, even though full automation often proves elusive or unnatural in many applications, where technology is expected to assist rather than replace the human agents.
MIPRCV establishes a five-years research programme to develop PR and CV approaches that explicitly deal with the challenges and opportunities entailed by the human-interaction paradigm. Based on these approaches, it also aims at implementing actual systems and prototypes for a number of important MI applications.



* IRI budget
Total budget: 4,5 M€

SGR-VIS

Grup de recerca consolidat - VIS

> Principal Investigator: *Alberto Sanfeliu*

The Vision and Intelligent Systems Group (VIS) carries out basic and applied research with the aim of understanding and designing intelligent systems that are capable of interacting with the real world in an autonomous and wide-reaching manner. Such intelligent systems must perceive, reason, plan, act and learn from previous experiences. The group works on the following topics: robust colour image segmentation and labelling, pattern recognition, viewpoint invariant object learning and recognition, object tracking, face tracking, biometrics, processing and analysis of medical images for diagnosis, document analysis, mobile robot navigation, simultaneous localisation and map building, visual servoing, and human-computer interaction. The possible areas of application of the VIS's research include the automotive and transport industry, the biomedical imaging industry, the space industry, robotics applications, security, home and office automation, the entertainment industry, and future computing environments.

SGR-Robòtica

Grup de recerca consolidat - Grup de Robòtica

> Principal Investigator: *Carme Torras*

The IRI Robotics group is a group of long tradition established in 1997. The research carried out in this group is organized around two complementary lines of research: "Perception and Manipulation" and "Kinematics and Robot Design" One objective is to improve the understanding of perceptual information geometry, and to build models of 3D objects in the context of domestic and service robotics. Following the approach of cognitive robotics, this group works on planning and action selection, reinforcement learning, and learning by demonstration. In "Kinematics and Robot Design" we deal with the analysis, design and construction of robot mechanisms, kinematic analysis (position and instantaneous motion), the definition of optimal designs (synthesis of mechanisms), the construction of physical prototypes, and the generation of collision-free motion.

3

PUBLICATIONS

Scientific publications

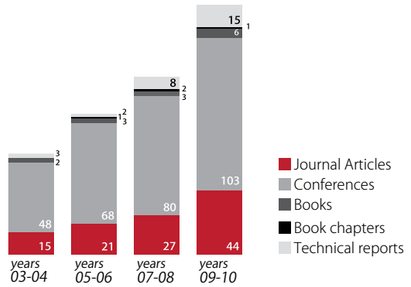
"The number of publications in 2009-2010 was 169, 40 % higher than in 2007-2008.

We are aware of the great importance of communicating our results to the scientific community. Therefore, our scientific production has grown considerably in the last years. Journal articles, conferences participation, books publication and own production are included in our production.

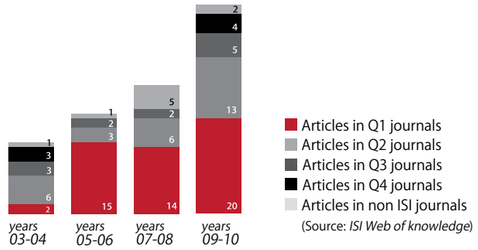
"Publication in top scientific journals in the first quartile of their respective areas has increased by 43 % in 2009-2010

We are not only enhancing the quality of our scientific throughput, but also its quantity. The number of publications has been doubled during the last six years.

>Publications trend



>Articles quality evolution



> Distribution of targeted journals in 2009-2010

11	9	7
Journals top quartile impact factor	Journals 2nd quartile impact factor	Other journals

Some IRI members participate in the Editorial Board of the following journals:

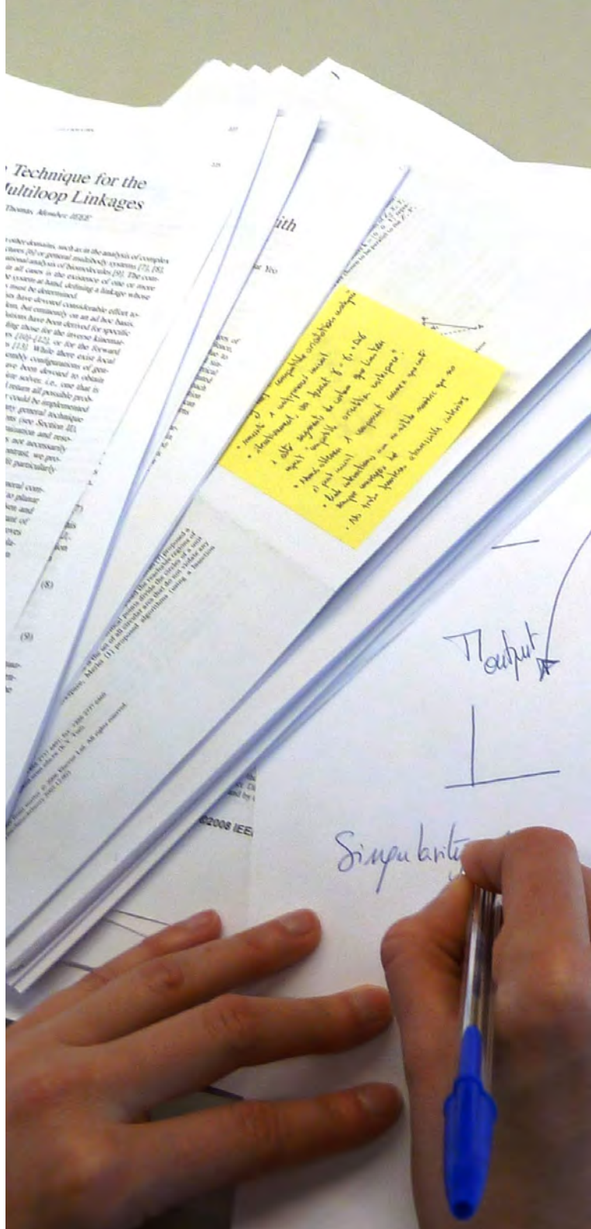
- IEEE Transactions on Robotics
- ASME Journal of Mechanisms and Robotics
- International Journal of Mechanics and Control
- Pattern Recognition Letters
- Int. Journal of Pattern Recognition and Artificial Intelligence
- Computer Vision and Image Understanding
- Revista Iberoam. de Automática e Informática Industrial

> Conference presence in 2009-2010

43	15	2
International ISI conferences	International non ISI conferences	National conferences

The following congresses were organized by IRI members:

- Workshop of Networks Robot Systems NRS at:
  - · IROS: IEEE/RSJ Int. Conf. on Intelligent RObots and Systems
  - · ICRA: IEEE Int. Conf. on Robotics and Automation
- Int. Conf. on Inform. in Control, Autom. and Robotics (ICINCO)
- ICCV 2011 (to be held in Barcelona in November 2011)



Scientific publications

JOURNAL ARTICLES

2010

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2010

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4

EDUCATION

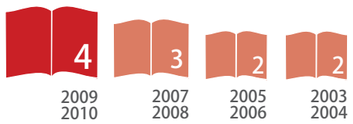
RESEARCH >

Education

"We are committed to excellence in higher scientific education, through the mentoring of undergraduate, masters and PhD students

Our teaching activity is varied and active. Proof of this, is that the number of PhD Students has been doubled in the last six years, and in the last two year period have been defended more PhD Theses than ever. Furthermore, we also support students who work in their Master Theses or "Final year projects".
As we can see in next page, our research staff teaches postgraduate as well as undergraduate courses. Moreover, we have other teaching activities as Seminar Series and the Humanoid Lab.

> PhD Theses defended in the last years:

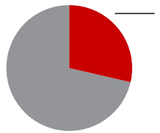


38 PhD Theses
under development in 2009-2010

18 Master Theses
defended in 2009-2010

10 Final year projects
defended in 2009-2010

> Teaching activities



28,6%
MASTER CLASSES
Our postgraduate teaching activities at UPC are included in:
> Master in Automatics and Robotics
> Master in Artificial Intelligence
> Master in Applied Mathematics

71,4%
UNDERGRADUATE CLASSES
Our faculty teaches undergraduate courses at UPC in:

ETSEIB Industrial Engineering

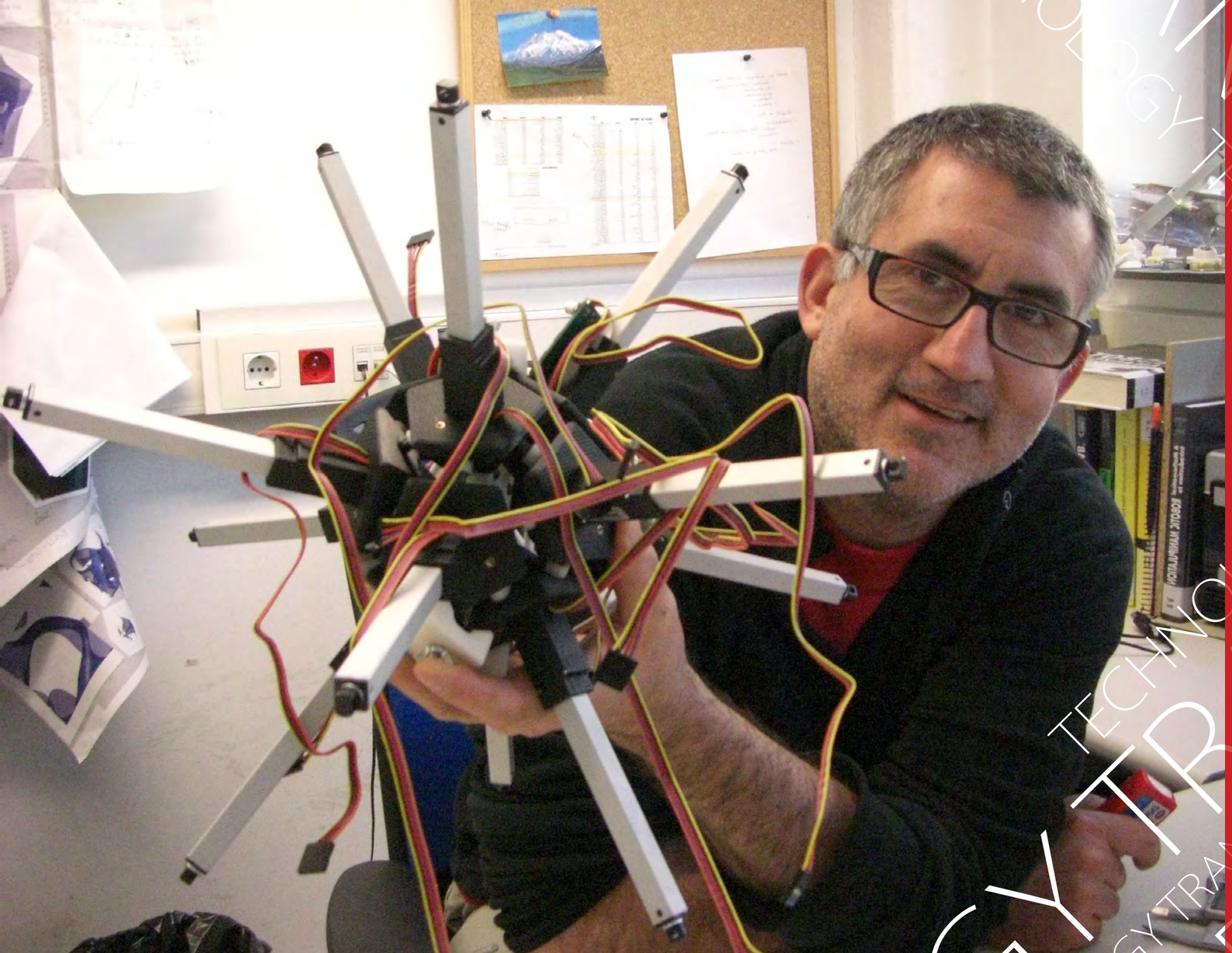
FIB Informatics

FME Mathematics and Statistics

ETSEIAT Industrial and Aeronautic Engineering (Terrassa)

Seminar Series:
The Institute holds an open seminar series to discuss our more recent research developments as well as those of other worldwide groups we cooperate with.

Humanoid Lab:
In addition, the Institute hosts the Humanoid Lab, offering undergraduate students a unique opportunity to familiarize with robotics research.



5

TECHNOLOGY TRANSFER

Overview

"Through agreements with industrial partners, the Institute seeks innovative solutions to real industrial problems.

Basic and applied research developed at the Institute is at the core of the methodologies and knowledge transferred to our diverse range of industrial partners. This transferred technology forms into new processes, applications, services and developed products.

> Technology transfer numbers:

6 **Technology transfer projects under development in 2009-2010**

642 **Thousand euros in technology transfer projects under development in 2009-2010**

53 Technology transfer projects developed in our center since 1995

In order to cover this important demand for technology transfer, the Institute has support facilities that not only allow developing prototypes and applications for the industry but also motivate the applied research, that opens new collaborations and agreements in other sectors. These facilities include the Perception and Manipulation Laboratory, the Kinematics and Robot Design Laboratory, the Mobile Robotics Laboratory, the Barcelona Robot Laboratory, the Fuel Cell Control Laboratory, and the Water-Cycle Process Control Laboratory. All these labs offer their services to the surrounding industrial community as well as to the academic community worldwide.

Technology transfer projects in the period 2009-2010

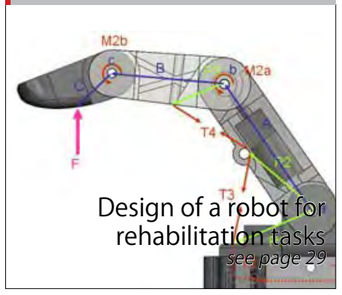
ELISSA-CRISALIDA:

Energy management
see page 51

CETAQUA

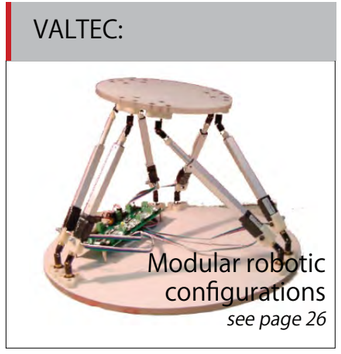
Water resources management
see page 53

IDAHO



Design of a robot for rehabilitation tasks
see page 29

VALTEC:

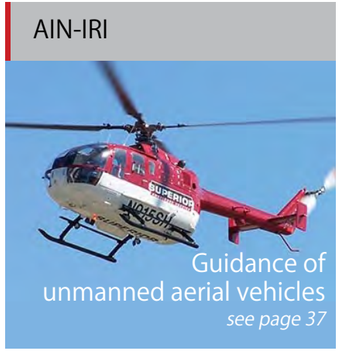


Modular robotic configurations
see page 26

MANIPTENS

New robot designs
see page 27

AIN-IRI



Guidance of unmanned aerial vehicles
see page 37

Industrial partners

The Institute has delivered in recent years solutions for energy routing on large distribution networks for Iberdrola, Repsol-YPF and SITEL among other companies, and on energy management on hybrid vehicles for LEAR.
Together with Agbar, CLABSA, and other groups at UPC, through Cetaqua, we promote and develop innovative solutions for management of the integral water cycle.
Our researchers have also developed, in cooperation with AIN, algorithms for the computation of time to collision for unmanned aerial vehicles; and consulted on mobile robot navigation for the company PAL-Robotics.
Within the URUS project, our researchers developed in collaboration with Telefónica I+D, systems for seamless routing of robot communication messages through Wifi and 3G networks. We have also developed various computer vision systems for the robotic manipulation and large vehicle autonomous navigation for the French company Robosoft.

Company: Agbar - *Aguas de Barcelona*
Project: Promotion and supervision of research projects related to efficiency in water networks

Company: Clabsa - *Clavegueram de Barcelona*
Project: Optimum control of urban drainage systems. implementation of an integrated tool for the global optimised control of a combined sewer network

Company: Telefónica I+D
Project: Ubiquitous networking robotics in urban settings

Company: IBERDROLA
Project: Supervisory algorithms for safe and efficient energy distribution

Company: LEAR Corporation
Project: Development of an electric energy management algorithm for an hybrid vehicle with double-bus architecture

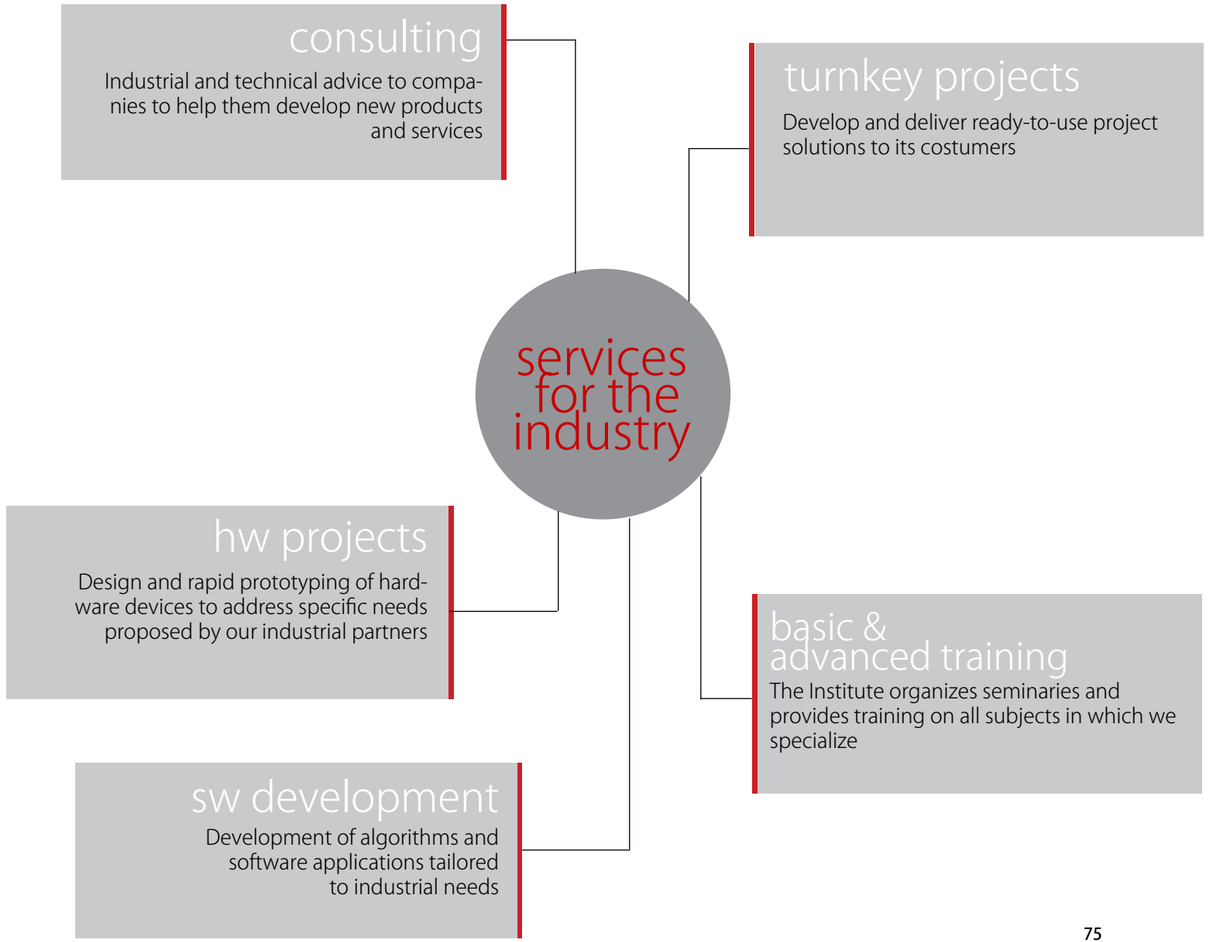
Company: AIN - *Asociación de la Industria Navarra*
Project: Obstacle avoidance for UAVs using computer *vision*

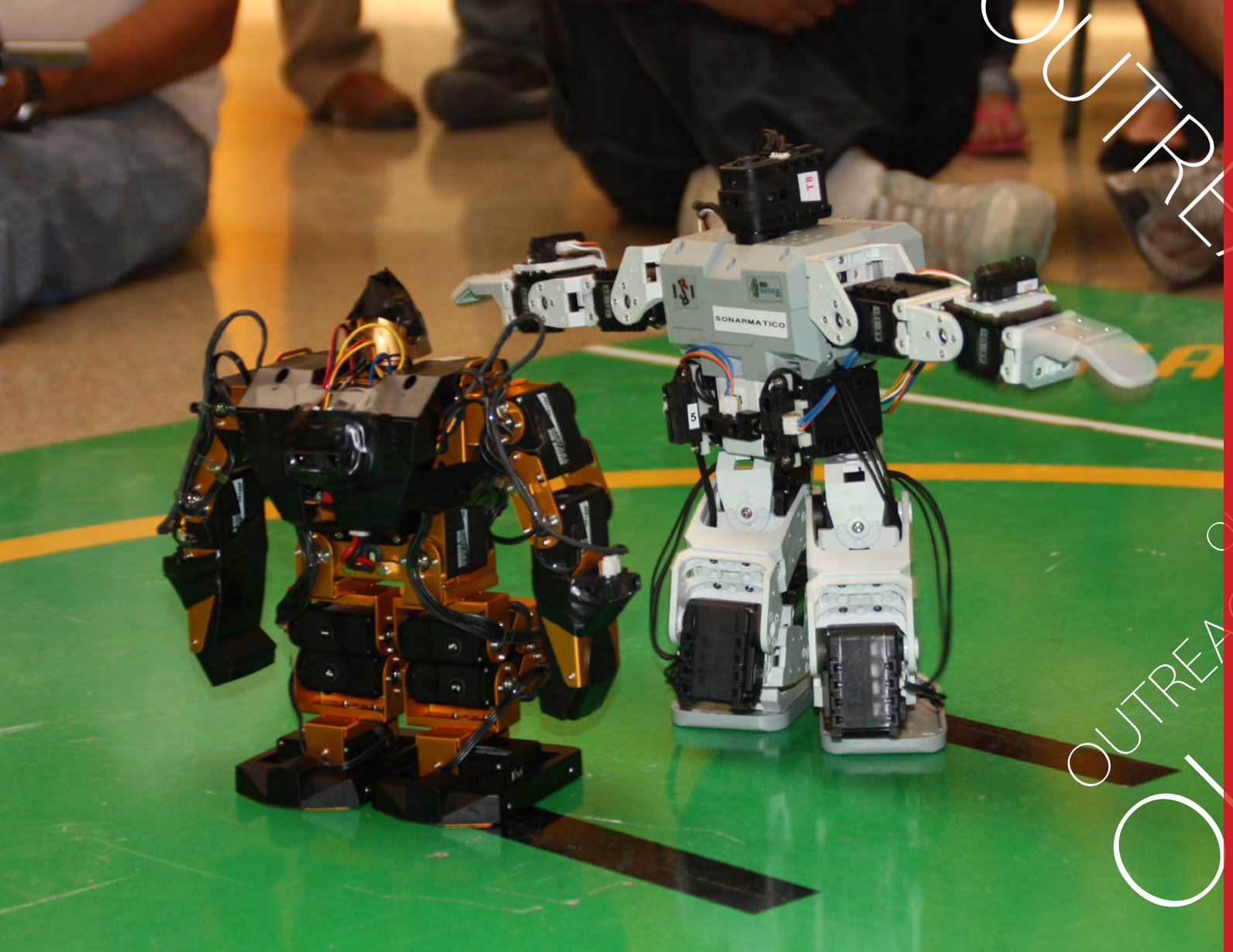
Company: Repsol-YPF
Project: Supervisory Algorithms for Safe and Efficient Energy Distribution

Company: PAL Robotics
Project: *Technological research to develop a support system for navigation of mobile robot*

Company: SITEL
Project: Supervisory Algorithms for safe and efficient energy distribution

Company: Robosoft
Project: Computer vision-based driver assistance for the NICOLAS-VTCU vehicle





6

OUTREACH

Media appearances

> IRI staff appeared in news from the main Spanish media: *El País*, *rtve.es*, TV3, ...

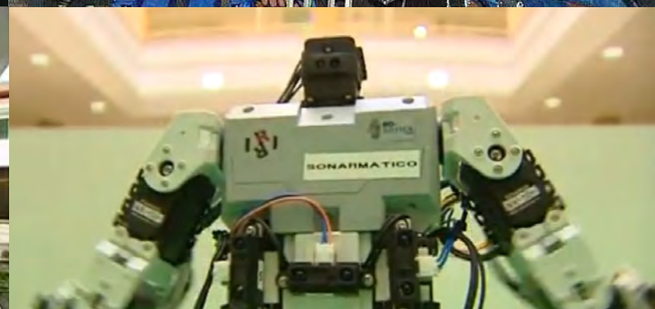
During the years 2009 and 2010, the presence of IRI in the media has been greater than ever, appearing in several newspapers and television and radio programs. This helps to increase the visibility of our research activities contributing to approach our science to the public. This is a very important fact in order to accomplish one of our main objectives: to improve the quality of life of the people.

Main media appearances in 2009-2010:

Newspapers:
El País
La Vanguardia
Diari Avui
Diario ADN
Diari L'independent de Gràcia
Informacions UPC

Television:
TV3
rtve.es
Euronews
Barcelona TV
Antena 3
Canal Sur

Radio:
CatalunyaRàdio
IcatFM



OUTREACH >

Activities

> We have participated in activities adressed to all types of public.

In the Institute we think that it is good to involve all our members in informative activities that attempt to bring our science to all audiences. For this reason, IRI staff participates frequently in many events such as seminars, workshops, talks, exhibitions, competitions...

Outreach activities in 2010:

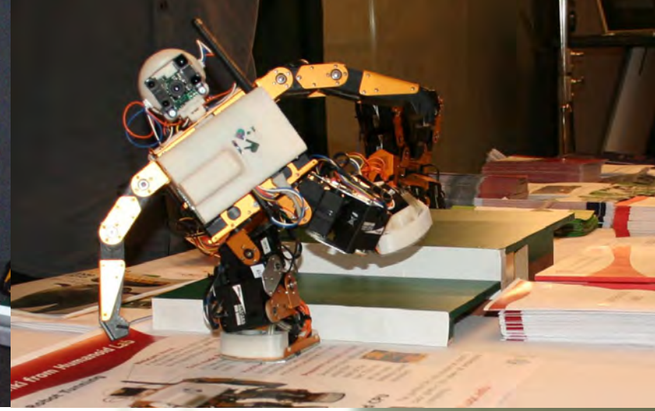
Urban Robots Presentation :
- Presentation of Tibi & Dabo Robots in the *Barcelona Robot Lab* - Barcelona, November 2009
- Presentation of Tibi & Dabo Robots from URUS project - Barcelona, July 2010

Festa de la Ciència 2010
Workshops, talks and activities - Barcelona, June 2010

SONAR Music Festival 2010
Invited participants to "Back to robots" exhibition in Sonarmàtica - Barcelona. June 2010

International Robot Contest Korea 2010
Participation as a invited team - Korea, October 2010

CEABOT'10
Participation in a robot competition with a team formed by IRI students - Jaén, September 2010



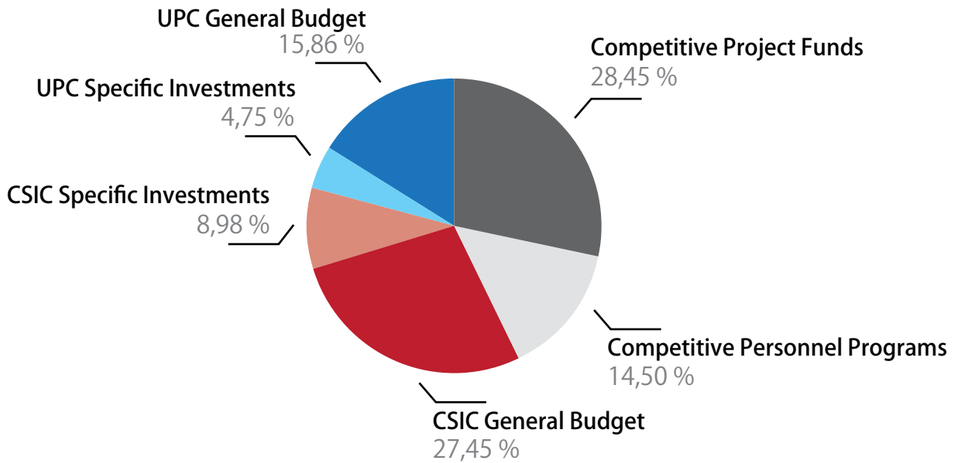
7

FUNDING

Budget

(Data of the period 2009-2010)

Total: 3.155.056,34 €



Expenses

(Data of the period 2009-2010)

Total: 3.158.702,17 €

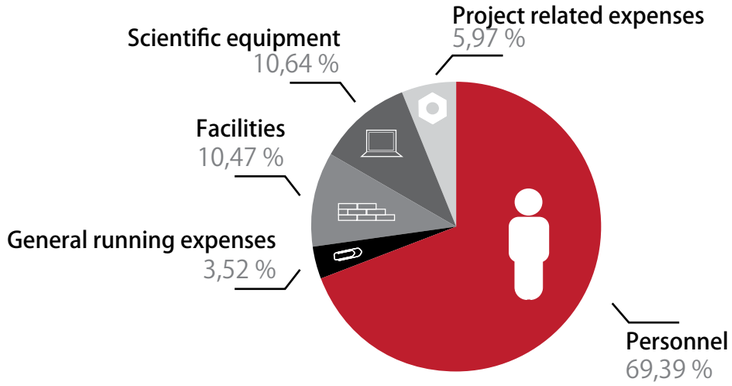


Photo credits

(PAGES):

cover
Tibi is a robot from URUS Project

2
Attila Husar and Miguel Allué working at the Fuel Cell Control Laboratory

5
Tibi outside the Institute

6
Teo robot takes a 3D range image of its developers Martí Morta, Ernesto Teniente and José Luis Rivero

9
Facade of the IRI facilities

11
The robot Teo from the PAU project

13 (from top to bottom)
1 Pol Monsó at the Perception and Manipulation Laboratory
2 Kinematics and Robot Design Laboratory

14 (from top to bottom)
1 Mobile Robotics Laboratory
2 Barcelona Robot Laboratory

15 (from top to bottom)
1 Attila Husar at the Fuel Cell Control Laboratory
2 Congcong Sun at the Water-Cycle Control Systems Laboratory

16
Workshop

17 (from top to bottom)
1 TIC service facilities
2 César González from the Administration team

18
(from left to right) Tibi Robot, Alberto Sanfeliu and Sergi Hernández at the Workshop

21 (from top to bottom)
1 WAM manipulator of the Perception and Manipulation Laboratory
2 Kinematics and Robot Design Laboratory
3 Tibi at the Mobile Robotics Laboratory
4 Jordi Riera at the Fuel Cell Control Laboratory

22
Aleix Rull (left) and Federico Thomas (right) at the Kinematics and Robot Design Laboratory

24
Josep Camps with a double platform

27
Júlia Borràs with parallel mechanisms

28 (from top to bottom)
1 Robotic hand from CUIK project
2, 3 Computed workspaces for the CUIK project

29
Results from the VALTEC project

30
Robot Tibi

32
Andreu Corominas with Tibi

33
Path planning, wheel odometry and localization estimate on a 2D map of the Barcelona Robot Lab

35
Tibi and Dabo

36
(from left to right) Gonzalo Ferrer, Joan Pérez and Eduard Trulls working on the guts of Tibi

38
GARNICS project

40
Leonel Rozo using a haptic device

41
Pol Monsó at the Perception and Manipulation Laboratory

43
WAM manipulator handling cloth

44 (from top to bottom)
1 Results from the BPnP project
2 Images from the GARNICS project

46
Gabriela Cembrano and Carlos Ocampo

48
Cristian Kunusch at the Fuel Cell Control Laboratory

51
Miguel Allué at the Fuel Cell Control Laboratory

52
Fuel Cell Laboratory

54
Ferran Cortés at Workshop

58
Montserrat Manubens working on singularities

66
Gonzalo Ferrer (left) and Eduard Trulls (right)

69 (from top to bottom)
1 Nicolás Rojas giving a talk
2 IRI's humanoid take part at CEABOT 2009 in Valladolid (Spain)

70
Patrick Grosch with a 12-dof ameba-like robot from the VALTEC project

73
A reconfigurable parallel platform

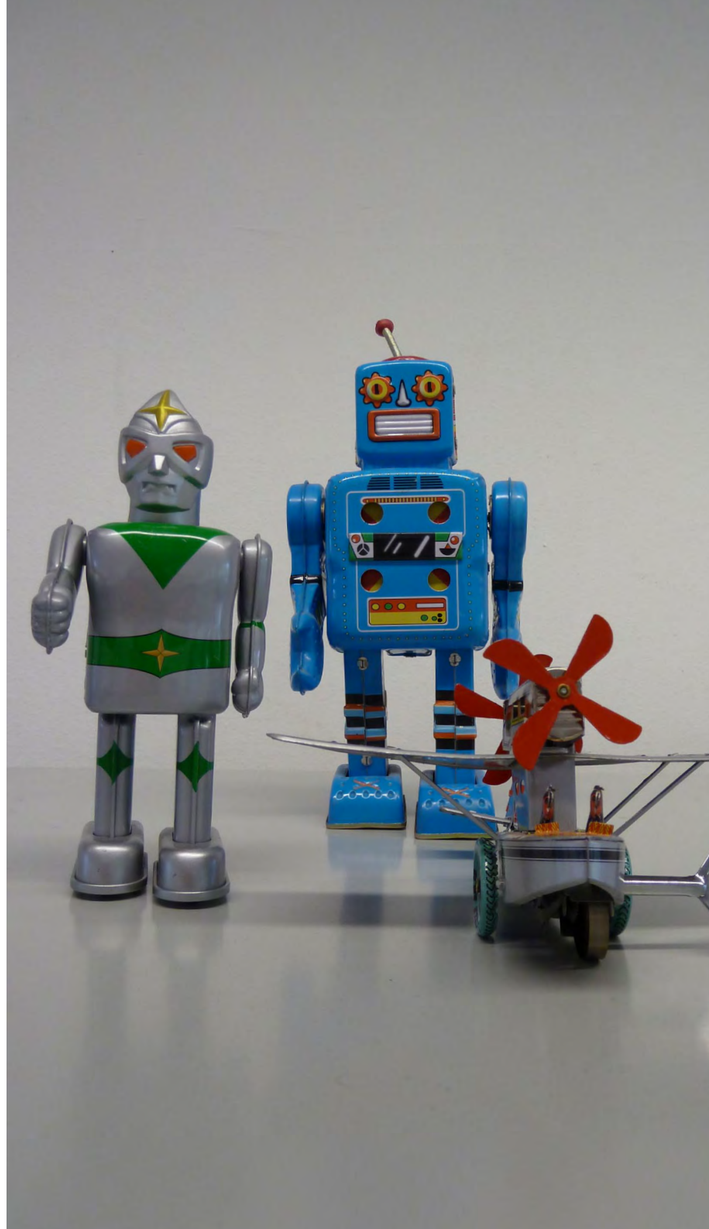
76
IRI Humanoid (right) at CEABOT 2010 in Jaén (Spain)

79 (from left to right and top to bottom)
1,2 TV appearance of the URUS project presentation and an interview to Alberto Sanfeliu at the TV program *Els Matins de Josep Cuní*, TV3, May 25th 2010
http://www.tv3.cat/videos/2918970
3 Humanoid Lab participation in CEABOT 2010, TV program *Noticias*, CanalSur, September 10th 2010
http://www.canalsur.es/portal_rtva/web/noticia?id=119392
4, 7 Alberto Sanfeliu with Dabo at the TV program *Futuris, Euronews*, 2009, http://www.urus.upc.es/
5 Juan Andrade gives a talk at *Festa de la Ciència*, Barcelona, June 2010, http://vimeo.com/13758238
6 *(first two people from left to right)* Sergi Hernández and Guillem Alenyà participate at the *International Robot Contest (IRC 2010)* in Korea , Photo: ROBOT Magazine, page 62.
8 Humanoid Lab participation in CEABOT 2010, Antena3, September 10th 2010
http://www.antena3.com/noticias/tecnologia/robots-humanoides-que-compitencomoluchadores_2010091000164.html

80
URUS presentation at *Passeig de Sant Joan*, Barcelona, May 2010

81 (from left to right and top to bottom)
1 José Luis Rivero shows Humanoid Lab robots at SÓNAR Music Festival, Barcelona, June 2010
2 Humanoid Lab robot in a presentation at the *Institut Municipal d'Educació de Barcelona*, September 2009
3 Aleix Rull gives a talk about the Humanoid Lab at the Institute IES Tecnos in Terrassa, 2010

87
Inhabitants of *Despatx 6*



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