Biennial Report
2011-2012
INDEX

1. OVERVIEW
   Description  7
   Organization 7
   IRI in numbers 9
   Facilities and services 10

2. RESEARCH
   Research projects 14
   Research lines 15
   Kinematics and Robot Design 16
   Mobile Robotics 24
   Perception and Manipulation 32
   Automatic Control 40
   Interdisciplinary research 48

3. PUBLICATIONS 50

4. EDUCATION 58

5. TECHNOLOGY TRANSFER 60
   Technology transfer projects 61
   Industrial partners 62
   Services for the industry 63

6. OUTREACH 64
   Activities 64
   Social networks 66
   Media appearances 66

7. FUNDING 68
The economic crisis is influencing the scientific and technological advances in Spain and probably will be more severe in the coming years. The research funds and the research positions have been drastically cut without a clear view when the tendency will be changed. In spite of this, Europe continues to strive for scientific and technological excellence in their research institutions and companies.

The Institute has followed this view and instead of losing hope, it has strengthened its efforts applying for European research funds with great success. In the last period, 2011-2012, we have started 6 new European research projects and we have worked in 33 research projects with an economic value of more than the 5.3 million Euros (18% more than in the last biennium). Our number and quality of peer-reviewed publications has also increased. We produced 161 publications of which 57 are journal articles (30% more than in the period 2009-2010). Of these, 68% appeared in top ranked journals. The number of PhD students has also increased and we now have 39 PhD theses under development.

The Institute has enlarged its research focus in robotics and control. In this period the robotic research area has started 2 new European projects, the first one IntellAct - Intelligent observation and execution of actions and manipulations, that addresses the problem of understanding and exploiting the meaning (semantics) of manipulations in terms of objects, actions and their consequenc- es for reproducing human actions with machines; and the second one, ARCAS - Aerial robotics cooperative assembly system, whose objective is the development and experimental validation of the first cooperative free-flying robot system for assembly and structure construc- tion. In the control research area, 4 new European projects have started, three related to fuel cell development, ACOFC - Advanced controllers and observers development for fuel cell based generation systems, ACRES - Advanced control of renewable energy gene- ration systems based on fuel cells/wind power, and PLAMA MIND - Physical bottom up multiscale modeling for automotive PEMFC innovative performance and durability optimization, and one related to the monitoring and control of drinking water networks, EFFINET - Effi- cient integrated real-time monitoring and control of drin- king water networks. In this period we have also ca- rried out 5 technological transfer projects with Spanish top companies in diverse topics in robotics and control.

The Institute opened in this period new outreach chan- nels with great success to address the general public through social networks such as Twitter, Facebook and YouTube. Moreover, in 2012, we participated in two fairs, the Saló International del Còmic (with more than 100,000 attendants) and Smart Cities in Barcelona, , in diverse dissemination activities like the European Robotics Week and the Spanish Science Week, and on industry dissemination activities such as the Consolider Ingenio 2010 Industry Day.

Our goal is pursuing the excellence in scientific and tech- nological research and its transfer to industry and so- ciety, with the hope that the same view that we have about R&D&I will be shared by our government.
The Institute has three main objectives: to promote fundamental research in Robotics and Applied Informatics, to cooperate with the community in industrial technological projects and to offer scientific education through graduate courses.

The Institute was created in November 1995 and 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.

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).

Director: Alberto Sanfeliu
Vice-Director: Juan Andrade
Department Head: Francesc Moreno
General Manager: Ana Canales
PhD Members Representative: Carlos Ocampo
PhD Students Representative: Sergi Foix
Support Personnel Representative: Patrick Grosch

Parc Tecnològic de Barcelona
C/ Llorens i Artigas 4-6, 08028 Barcelona

Description

Overview

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

During 2011-2012 we worked in 33 research projects (8 more than in 2009-2010)

The economic value of our projects in the last biennium was 5.39 millions of Euros (18% more than in 2009-2010)

Our self-funding has reached 54% of our budget, a very large number for a public research center.

We have started 6 new European Projects in the last biennium

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

12 PhD theses were presented in 2011-2012

We have 39 theses under development: more than ever

In 2011-2012 we have produced 161 publications, with 57 journal articles (30% more than in 2009-2010)

Publications in top scientific journals in the first quartile of their respective areas increased by 18% in 2011-2012, and now represents 68% of all our journal articles.

In 2011-2012 we carried out 5 technology transfer projects

Our self-funding has reached 54% of our budget, a very large number for a public research center.
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 kinds, 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

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

Services

- Mechatronics Workshop
- IT Services
- Administration

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 configurable 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. The laboratory service offers quick experimental setup, several standardized software tools, and expertise in robot control and perception algorithms. This lab 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 V ALTEC program of the Catalonian Government, co-financed with FEDER funds. 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 researchers of the Kinematics and Robot Design Group 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, 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, provided with 21 fixed cameras, a set of heterogeneous robots, full WiFi coverage, and partial GPS coverage. This laboratory is used for urban pedestrian mobile robotics research in national and European projects.

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 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 modeling 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.

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 machinery and a 3D plastic printer.

IT Services
The IRI IT service (IRITIC) is responsible for all the computer and communications infrastructure of the Institute, as well as user support. We have a small data center properly suited with rack servers and communications devices. Our network resources include cable networks (Ethernet) and wireless (Wi-Fi).

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 and outreach activities.

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

José Lázaro
Evili del Río
José Luis Roncero
Eduardo Wass

Ferran Cortés
Patrick Goseck

Barcelona Robot Laboratory
Fuel Cell Control Laboratory
Water-cycle Control Systems Laboratory
Mechatronics Workshop
IT Services
Administration
Research

IRI’s research activities are funded primarily by grants from the EU FP7 Research Programme and by competitive funds from the Spanish Ministry of Economy and Competitiveness 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

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 environmental resources, and on the management in the water and energy fields.

Research lines

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

<table>
<thead>
<tr>
<th>Research projects</th>
<th>BUDGET (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Projects: 9</td>
<td>3,760,317</td>
</tr>
<tr>
<td>National Projects: 10</td>
<td>1,898,330</td>
</tr>
<tr>
<td>Tech. Transfer Projects: 5</td>
<td>452,011</td>
</tr>
<tr>
<td>Regional Projects: 2</td>
<td>96,640</td>
</tr>
<tr>
<td>CSIC Projects: 6</td>
<td>10,103</td>
</tr>
<tr>
<td>UPC Projects: 1</td>
<td>20,000</td>
</tr>
<tr>
<td>TOTAL: 5,388,598</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NUMBER of running projects in the period 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Projects: 9</td>
</tr>
<tr>
<td>National Projects: 10</td>
</tr>
<tr>
<td>Tech. Transfer Projects: 5</td>
</tr>
<tr>
<td>Regional Projects: 2</td>
</tr>
<tr>
<td>CSIC Projects: 6</td>
</tr>
<tr>
<td>UPC Projects: 1</td>
</tr>
<tr>
<td>TOTAL: 33</td>
</tr>
</tbody>
</table>
The Kinematics and Robot Design Group carries out fundamental research on the 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, such as mechanical models of locomotive organisms, molecular compounds, or nano-structures.

During the period 2011-2012, 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 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 at all times.

Our 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 four principal lines: Robot design and construction, Position analysis of multi-loop linkages, Motion planning and singularity analysis.
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.

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 link 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.

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 in 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.

Singularity analysis
Singularities play a prominent role in the 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 normal operation of a robot. They may, however, give rise to a mechanical advantage too - i.e., to the transformation of small joint torques into large end-effector forces - which may be beneficial in 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.
The 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.

**CUIK++**

An extension of branch-and-prune techniques for motion analysis and synthesis of complex robotic systems

**PROSURF**

Superficies programables

The objective of the project is the design of surfaces that can morph into different shapes on command. The key of our approach is the mathematical treatment of the unit-to-whole and inverse whole-to-unit relation. We are interested on how to efficiently extend the properties of individual cells and neighboring relations to the global motion of a complex surface; and inversely, how to map global surface properties to candidate unit cells. Programmable surfaces could be used for deployable architectural and space systems, morphing power elements such as aircraft wings, turbine blades or solar panel arrays, and biomimetic robotics.

**VALTEC**

System of reconfigurable parallel robots

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 reconfigure the designed robot 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.
The goal of this project is to build a flexible toolbox for motion analysis and construction of planar manipulators. Planar manipulators are selected for this end because they allow for a more visual interpretation of the motion capabilities when compared to their spatial counterparts, yet still retaining the variety of complex kinematic phenomena that may be encountered in practice.

In order to fully illustrate all these phenomena, the project aims at exploiting previous experience gained during the VAITEC and Cuik++ projects, to design and manufacture a set of basic pieces that can be assembled to form different manipulators of this kind, as well as an associated software platform able to perform a full analysis of their workspace boundaries, singularities, and to plan singularity-free transitions between given configurations. Therefore, this toolbox can be a highly useful tool to support both the teaching of robot kinematics principles at the university level, and the empirical demonstration of advanced scientific results. Additionally, the toolbox will be offered to the scientific community, thus helping to disseminate the knowledge of the proposing group, as well as to increase its international visibility.

**CUIK-IT**
Un sistema modular para el análisis cinemático y la construcción de manipuladores planares

- Principal Investigator: Montserrat Manubens
- Period: January 1 to December 31, 2013
- Budget: 15,000 €
- Type: CSIC Project

**IDAH0**
Kinematics synthesis for a scalable finger/thumb exoskeleton robot

- Principal Investigator: Alba Pérez
- Period: March 1 to February 28, 2011
- Budget: 8,400 €
- Type: Tech. Transfer Project

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 over-constrained 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.
Research line: Mobile Robotics

The Mobile Robotics group performs research on human service robotics, with emphasis on urban scenarios. 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.

In the period 2011-2012 we have continued our line of national projects addressing various collaborative perception and navigation challenges for land robots and have also commenced participation in a line of projects contributing perception solutions in the aerial robotics domain.

Objectives

The research activities of the Mobile Robotics line are aimed to endow mobile robots and ubiquitous computing devices with 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

Researchers: René Alquézar, Juan Andrade, Ivan Huerta, Alberto Sanfeliu, Michael Villamizar

PhD Students: Adrián Amor, José R. Capriles, Andreu Corominas, Diego Escudero, Gonzalo Ferrer, Aris Gavriel, Alex Gómez, Edmundo Guerra, Luis Martínez, Àngel Martínez, Adrián Peñate, Eloy Retamino, Gerard Sanromà, Àngel Santamaría, Eduard Serradell, Rafael Valencia, Eduard Trulls

Support Staff: Fernando Antelo, Joan Aleu, Alberto Sanfeliu P.

Support Staff: Fernando Antelo, Joan Aleu, Alberto Sanfeliu P.
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 behavior, 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 sensing 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.
The Collective Experience of Empathic Data Systems (CEEDS) consortium advances a novel integrated technology that supports the experiencing, analyzing and understanding of massive datasets. A 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 achieved 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.

The Arcas project proposes the development and experimental validation of the first cooperative free-flying robot system for assembly and structure construction. The project will pave the way for a large number of applications including the building of platforms for evacuation of people or landing aircrafts, the inspection and maintenance of facilities and the construction of structures in inaccessible sites and in the space.

The detailed scientific and technological objectives are: new methods for motion control of a free-flying robot with mounted manipulator in contact with a grasped object as well as for coordinated control of multiple cooperating flying robots with manipulators in contact with the same object; new flying robot perception methods to model, identify and recognize the scenario and to be used for the guidance in the assembly operation; new methods for the cooperative assembly planning and structure construction by means of multiple flying robots with application to inspection and maintenance activities; and strategies for operator assistance in manipulation tasks involving multiple cooperating flying robots.

The use of robots will be in the near future extended to new demanding applications to help humans in everyday tasks, where cooperative and 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 perception (network cameras) perception system. Specifically we want to advance in the development of new techniques in localization and navigation 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).
The project goal is to contribute to the theoretical foundations of computational models of perception and action and their application to the solution of challenging robotics problems with large state spaces. The majority of the methods and techniques studied in this project have as pillars Bayesian estimation on one side, and geometrical models in robotics and computer vision on the other.

The application domains of the project are mobile robot mapping and navigation, and perception and manipulation of deformable objects. Although very different in nature, these two applications share many similarities with respect to the formalism of perception, estimation and exploration. The most important aspect is that both types of systems are commonly represented with very large state spaces.

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.

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.

In this project we developed techniques to compute time to collision measures for the autonomous guidance of unmanned aerial vehicles (UAVs) for the cooperative building of structures. This requires the use of computer vision techniques for the detection, identification, and tracking of the structure elements. The detection and identification tasks are necessary for the localization of objects and to determine grasping and assembly poses. Experiments will be performed both in indoor and outdoor settings where illumination, wind, and other environmental factors cannot be predicted. Moreover, assembly operations need to be executed in real time, which makes the challenge even more complex.
Research line: Perception and Manipulation

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.

Carme Tarras
Research Head

Researchers:
- Alejandro Agostini
- Maria Alberich
- Guillem Alenyà
- Babette Dellen
- Pablo Jiménez
- Francesc Moreno
- Diego Pardo
- Arnau Ramisa
- Carme Tarras

PhD Students:
- Adrià Colomé
- Sergi Foix
- Farzad Husain
- David Martinez
- Leonel Rozo
- Edgar Simó

Support Staff:
- José L. Rivero
- Iván Rojas
- Nàdia Tolós

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
Learning by demonstration
We devise methods to learn 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 are 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 specific sequences of motion commands.

Perception of rigid and non-rigid objects
Our objective is to investigate computer vision algorithms for interpreting and understanding scenes from images, with applications in robotics and medical imaging. In particular, our activities are concentrated on retrieving rigid and non-rigid shape, motion and camera pose from single images and video sequences.
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 plant 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).

**IntelliAct**

IntelliAct 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 IntelliAct. Based on the semantic interpretation and description and enhanced with low-level trajectory data for grounding, two major application areas are addressed by IntelliAct: the monitoring of human manipulations for correctness and the efficient teaching of cognitive robots for manipulation. To achieve these goals, IntelliAct 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.

**APREN**

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, 10f sensors and haptic displays into the learning schemes.
The two robot WAM arms in the Perception and Manipulation laboratory can be placed in various relative configurations, some away from the standard anthropomorphic one, in order to improve their manipulability for specific tasks. In this project, their configuration will be optimized for tasks involving the manipulation of deformable surfaces (clothing, paper, plant leaves), and kinematic modeling, dynamic simulation, perception and learning algorithms will be developed for this challenging setting.

### MVOD
*Medición eficiente de volúmenes de objetos deformables con cámaras rentables*

The measurement of object volumes is of large importance in many sectors of industry, including agriculture, transportation, production, and forestry. In this project, we investigate the feasibility of using low-cost depth-sensing devices such as the Kinect camera for volume measurement of objects of medium size, e.g., parcels and other domestic objects, including the deformable objects. Using a fixed set-up, depth data is acquired from different viewpoints and merged. Volumes are carved using a volume intersection approach, which is computationally simple, and, most importantly, model-free. Particular attention is given to the characteristic properties of the data acquired with the Kinect, such as the limited resolution, among other typical contingencies. The performance of the method is evaluated using ground-truth volumes of a benchmark data set of selected objects, and volume-measurement errors are estimated. The computational efficiency of the applied algorithms for volume measurement represents another important aspect of the project, since the computation speed largely determines how many objects can be measured during a day, which should be as large as possible.

### Humanoid Lab
*The Humanoid Laboratory*

This project is mainly addressed to students interested in learning basic concepts of robotics. Hosted at the Institut de Robòtica i Informàtica Industrial, our goal is to introduce engineering and mathematics students to the robotics world. Our philosophy: learning, technology and openness.
Research line: Automatic Control

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 large-scale systems. The group has acquired specific expertise in the application of advanced control techniques to environmental and natural resources management, specifically in the water and energy fields. The research is oriented towards improving the efficiency in real-life industrial processes, such as power generation systems, water supply and distribution networks, urban drainage, power supply grids, among others.

The group takes part in scientific and industrial projects at a national and European level as well as in several collaborative modeling of dynamical systems and advanced automatic control for undergraduate, MSc and PhD students from UPC and 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 and large-scale systems;
- Contribution to improving the efficiency of industrial processes, specially in the fields of water and energy;
- Implementation of the proposed methodologies and designs in real systems; and
- Training of research staff and students in the field of automatic control.

Personnel

Researchers: Gabriela Cembrano, Attila Husar, Cristian Kunusch, Carlos Ocampo, Vicenç Puig, Paul Puleston, Jordi Riera, Albert Rosich, Maria Serra

PhD Students: Vanesa García, Juan Manuel Grosso, María Laura Sarmiento, Stephan Strahl, Congcong Sun, Feng Xu

Support Staff: Tom Creemers, Vicente Roda, Redjane Vito, José Sánchez

Support Staff in 2011-2012:

- Tom Creemers
- Vicente Roda
- Redjane Vito
- José Sánchez
The group’s general scientific objective is the advancement in the field of modeling, supervision and control of complex and large scale systems, including nonlinearities and uncertainty with the aim to improve efficiency, reliability and sustainability of processes and systems. The most relevant application fields, for which the group has acquired recognized expertise are: systems in the water cycle (water resources management, water distribution, urban drainage) and energy systems (fuel cells, hydrogen-based energy systems, energy generation for autonomous mobile systems, power distribution management).

Modeling, supervision and control of complex multi-domain systems
The development of control-oriented models and the design of advanced controllers for complex dynamic systems where phenomena of different nature are interrelated is another fundamental research topic of the group, where the experimental work and the real implementation is a fundamental aspect. It includes distributed and lumped parameters control-oriented modeling, experimental characterization techniques, identification, diagnosis, design of observers, sliding mode control, robust control and predictive control. Applications fields: polymeric exchange membrane fuel cells, power generation systems, ethanol reformers for hydrogen production.

Control-oriented system design for efficient operation
Efficiency, reliability and sustainability of processes and systems depend on different design aspects which are also addressed by the group researchers. This includes topology selection or reconfiguration, sizing of components, structural analysis, and sensor and actuator location. Applications fields: water networks, electrical grids, autonomous power generation systems, robotics.
Drinking water utilities in urban areas are facing new challenges in their real-time operation because of limited water resources, intensive energy requirements, a growing population, a costly and ageing infrastructure, increasingly stringent regulations, and increased attention towards the environmental impact of water use. Such challenges force water managers to monitor and control not only water supply and distribution, but also consumer demand. This project proposes a novel integrated water resource management system based on advanced ICT technologies of automation and telecommunications for largely improving the efficiency of drinking water networks in terms of water use, energy consumption, water loss minimization, and water quality guarantees. Two real-life pilot demonstrations in Barcelona (Spain) and Lemesos (Cyprus), respectively, will prove the general applicability of the proposed integrated ICT solution and its effectiveness in the management of drinking water networks, with considerable savings of electricity costs and reduced water loss while ensuring the high European standards of water quality to citizens.

### EFFINET

**Efficient integrated real-time monitoring and control of drinking water networks**

- **Scientific and Technical Supervisor:** Gabriela Cembrano
- **Period:** Oct 1 - Sep 15
- **IRI Budget:** 273534 € (Total 2192290 €)
- **Type:** European Project

Proton Exchange Membrane Fuel Cells (PEMFCs) are complex nonlinear systems. In order to improve their durability, efficiency and to decrease the cost, time of development, design of new diagnostic tools is crucial. Powerful mathematical models of the dynamic behaviour of PEMFCs are necessary for the design and improvement of diagnostic tools. This project will enhance the understanding of interaction, competitions and synergies among the mechanisms at multiple scales and lead to the development of robust dynamic macroscopic models for control-command purposes with predictive capabilities. The novel mathematical models developed will be tested by an experimental work, in order to ensure the applicability on commercial attainable components and catalysts. The most suitable catalysts for the MEA manufacturing technology will be used for these experiments. The implementation of the developed models on the mentioned above catalysts might allow a significant impact, and might also contribute to the most promising solutions based on current EU industrial available components. Operation conditions and control strategies to enhance the durability of automotive PEMFC will be derived on the basis of the multiscale modeling approach proposed by PUMA MIND.

### PUMA MIND

**Physical bottom-up macroscale modelling for automotive FC-MEC innovative performance and durability optimization**

- **Leader for R:** Jordi Riera
- **Period:** Dec 12 - Dec 15
- **IRI Budget:** 273495 € (Total 2294106 €)
- **Type:** European Project

Proton Exchange Membrane Fuel Cells (PEMFCs) are complex nonlinear systems. In order to improve their durability, efficiency and to decrease the cost, time of development, design of new diagnostic tools is crucial. Powerful mathematical models of the dynamic behaviour of PEMFCs are necessary for the design and improvement of diagnostic tools. This project will enhance the understanding of interaction, competitions and synergies among the mechanisms at multiple scales and lead to the development of robust dynamic macroscopic models for control-command purposes with predictive capabilities. The novel mathematical models developed will be tested by an experimental work, in order to ensure the applicability on commercial attainable components and catalysts. The most suitable catalysts for the MEA manufacturing technology will be used for these experiments. The implementation of the developed models on the mentioned above catalysts might allow a significant impact, and might also contribute to the most promising solutions based on current EU industrial available components. Operation conditions and control strategies to enhance the durability of automotive PEMFC will be derived on the basis of the multiscale modeling approach proposed by PUMA MIND.

### MESPEM

**Powerful mathematical models of the dynamic behaviour of PEMFCs are necessary for the design and improvement of diagnostic tools. This project will enhance the understanding of interaction, competitions and synergies among the mechanisms at multiple scales and lead to the development of robust dynamic macroscopic models for control-command purposes with predictive capabilities. The novel mathematical models developed will be tested by an experimental work, in order to ensure the applicability on commercial attainable components and catalysts. The most suitable catalysts for the MEA manufacturing technology will be used for these experiments. The implementation of the developed models on the mentioned above catalysts might allow a significant impact, and might also contribute to the most promising solutions based on current EU industrial available components. Operation conditions and control strategies to enhance the durability of automotive PEMFC will be derived on the basis of the multiscale modeling approach proposed by PUMA MIND.**

### WATMAN

**Analysis and design of distributed optimal control strategies applied to large-scale water systems management**

- **Principal Investigator:** Gabriela Cembrano
- **Period:** Jan 10 - Dec 12
- **Budget:** 196.020 €
- **Type:** National Project

The WATMAN Project deals with the global management of the hydric networks related to the UWC networks. This management not only comprises the design of control strategies to fulfil performance objectives but also includes the development of a control-oriented modelling for the UWC networks. This management not only comprises the design of control strategies to fulfil performance objectives but also includes the development of a control-oriented modelling for the UWC networks. This management not only comprises the design of control strategies to fulfil performance objectives but also includes the development of a control-oriented modelling for the UWC networks. 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.
**Research projects**

**CETAQUA**

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

- **Principal Investigator**: Gabriela Cambraio
- **Type**: Transfer Project
- **Budget**: 250,000 €

The collaborative project between RTH 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.

**CORAL**

Coral upgrade RCT1201

- **Principal Investigator**: Vicenç Puig
- **Type**: Transfer Project
- **Budget**: 25,000 €

As result of the AM061 Project “Optimum Control of Urban Drainage Systems”, where CORAL tool was evaluated against a real case study (Riera Blanca), some improvements in the modelling part of the tool have been suggested. In particular, the current RCT1201 project addresses the following CORAL improvements: In-line retention in sewers, Multi-compartment tanks, weirs controlled by water level, run-off modelling improvements: In-line retention in sewers, Multi-compartment tanks, weirs controlled by water level, run-off modelling.

**ACRES**

Advanced control of renewable energy generation systems based on fuel cells/wind power

- **Principal Investigator**: Jordi Riera
- **Type**: European Project
- **Budget**: 7,800,000 €

The objective of this project is the development of advanced controllers capable to improve the efficiency of fuel cells/wind power based DES. They will be implemented and tested in the ACES labs in Barcelona. The results of this implementation will be used to assess the theoretical developments and will also provide a technology demonstrator to aid technology transfer to industry.

**ACOF**

Advanced controllers and observers development for fuel cell based generation systems

- **Principal Investigator**: Cristian Kunusch
- **Type**: European Project
- **Budget**: 100,000 €

The activities proposed in this project strive for providing novel and practical responses to the actual requirement of efficiency and lifetime improvement of PEM fuel cells based generation systems. Special efforts will be focused on obtaining innovative results in the area of PEM fuel cells control oriented models, dynamic estimation of states and nonlinear control based on Higher Order Sliding Modes. Considerable work with new controllers depending on a desired system performance. Additionally, it is expected to complement the proposed control designs with other modern control strategies such as model predictive control (MPC).

**ACRES**

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

- **Principal Investigator**: Gustavo Sanz
- **Type**: National Project
- **Budget**: 700,000 €

The aim of the project is to improve the PEMFC systems performance and to take full advantage of PEMFC integration into Distributed Electrical Generation Systems. The 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.

**MACPERCON**

Enhanced management topologies based on an unfalsified control for PEM fuel cells performance improvement

- **Principal Investigator**: Carlos Ocampo
- **Type**: CSIC Project
- **Budget**: 11,685,200 €

MACPERCON explores the way of analysing, designing and implementing novel controllers not used so far in the field of highly complex systems such as fuel cells. The particular strategy corresponds with the unfalsified control, which is based on the idea of commutation of controllers depending on a desired system performance. Additionally, it is expected to complement the proposed control designs with other modern control strategies such as model predictive control (MPC).

**ACOI**

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

- **Principal Investigator**: Jordi Riera
- **Type**: National Project
- **Budget**: 1,050,000 €

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 more sub-systems 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.
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 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.

**MIPRCV**

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

| Leader for MI | Alberto Sanfeliu |
| Team Size | 648000 € (Total: 4.5 M€) |
| Type | National Project |

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 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.

**SGR-VIS**

Grup de recerca consolidat-VIS

| Principal Investigator | Alberto Sanfeliu |
| Period | Sep09-Dec13 |
| Budget | 48800 € |
| Type | Regional Project |

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-Robòtica

| Principal Investigator | Carme Torras |
| Period | Sep09-Dec13 |
| Budget | 47840 € |
| Type | Regional Project |

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 motions), the definition of optimal designs (synthesis of mechanisms), the construction of physical prototypes, and the generation of collision-free motion.
In 2011-2012 we have maintained the high number of publications of 2009-2010, but increasing its quality by publishing more journal articles.

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, and book authoring are included in our production.

Publication in top scientific journals in the first quartile of their respective areas has increased by 18% in 2011-2012, and now represents a 68% of all journal articles.

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

In November 2011, our Institute co-organized the International Conference on Computer Vision (ICCV2011).

Furthermore, in 2013 we will organize two conferences:
- 6th International Workshop on Computational Kinematics (ICK2013) to be held in May
- 6th European Conference on Mobile Robots (ECMR2013) to be held in September
8th International Conference on Computer Vision Theory and Applications. 2011, Providence, Rhode Island, pp. 1885-1891, IEEE.

E. Simo-Serra, A. Ramisa, G. Alenyà, C. Torras and F. Moreno-Noguer. Robust feature point descriptor, 13th International Conference of the Catalan Association for Artificial Intelligence, 2011, Tarragona, Spain, pp. 349-352, LITEC.


Concurrent, full papers, in Computer Science, pp. 110-115, Springer.

Recognition, Vol 6658 of Lecture Notes in Computer Science, M. Villamizar, H. Grabner, J. Andrade-Cetto, A. Sanfeliu, L. Van Mellelles. Smooth simultaneous structural graph matching and point-set registration, 8th IAPR Workshop on Graph-based Representations in Pattern Recognition, full papers, in Computer Science, pp. 6-11, Springer.

Working memory systems, 18th IFAC World Congress, 2011 Milano, Italy, pp. 434-440.


Tuning of predictive controllers for drinking water distribution systems, S. Gonzalez, P.F. Puleston and E. Fossas. Diseño de un convertidor CC-CC doble boost acoplado, 16th International Conference on Electrical Power Quality and Synchrophasor Applications, 2011, Barcelona, Spain, pp. 139-144, IEEE.


C. Alenyà, P. Grosch, C. Torras. Robot Tensegrítico, Oficina Española de Patentes y Marcas, Solicitud P2009/004681, Application date: 14-September-2009, Granting date: 01-February-2010.

C. Alenyà, P. Grosch, C. Torras, M. Palacín. Herramienta para corte y extracción de muestras, Oficina Española de Patentes y Marcas, Solicitud P2012/002552, Application date: 14-September-2012, Granting date: 01-April-2013.

J. Andrade-Cetto. On the design of an algorithm for estimating the plant development parameters of a Tomato plant using photogrammetry, International Conference on Computer Vision, 2011, Spain, pp. 4-10, IEEE.

J. Andrade-Cetto. On the design of an algorithm for estimating the plant development parameters of a Tomato plant using photogrammetry, International Conference on Computer Vision, 2011, Spain, pp. 4-10, IEEE.

J. Andrade-Cetto. On the design of an algorithm for estimating the plant development parameters of a Tomato plant using photogrammetry, International Conference on Computer Vision, 2011, Spain, pp. 4-10, IEEE.
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 a record number of PhD Theses were finalized. Furthermore, we also support students who work in their Master Theses and “final year projects”.

Our research staff teaches graduate and undergraduate courses at various UPC schools. Moreover, we hold a regular Seminar Series and the Humanoid Lab.

PhD Theses defended:

- **2011 - 2012**: 12
- **2009 - 2010**: 8
- **2007 - 2008**: 3
- **2005 - 2006**: 2
- **2003 - 2004**: 1

Teaching activities:

- **23.3 %** MASTER CLASSES
  - Our postgraduate teaching activities at UPC are included in:
    - Master in Automatics and Robotics
    - Master in Artificial Intelligence
    - Master in Applied Mathematics

- **76.7 %** UNDERGRADUATE CLASSES
  - Our faculty teaches undergraduate courses at UPC in:
    - Industrial Engineering
    - Informatics
    - Mathematics and Statistics
    - Industrial and Aeronautic Engineering (Telematic)

Students:

- PhD Theses defended in 2011 - 2012: 12
- Master Theses defended in 2011 - 2012: 18
- Final year projects defended in 2011 - 2012: 3

Seminar series:

The Institute holds an open seminar series to discuss our most 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.
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.

In order to cover this important demand 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.

Technology Transfer projects in the period 2011-2012

- **CETAQUA**: Water resources management
- **IDAHO**: Design of a robot for rehabilitation tasks
- **VAITEC**: Modular robotics configurations
- **CORAL UPGRADE**: Control of Urban Drainage Systems
- **AIN-IRI**: Guidance of unmanned aerial vehicles

Technology Transfer numbers:

- 5 Technology transfer projects under development in 2011-2012
- 452 Thousand euros in technology transfer projects under development in 2011-2012
- 54 Technology transfer projects developed in our center since 1995
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.

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.
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, our staff participates frequently in many events such as seminars, workshops, talks, exhibitions and competitions.

**Outreach activities in 2011-2012**

- 2011 and 2012 edition of Setmana de la Ciència
- 2011 and 2012 edition of European Robotics Week
- Saló del Còmic 2012, Barcelona
- Smart City Expo World Congress 2012, Barcelona
- Campus Party 2011, València
- Exhibition “I/O/I: Els sentits de les màquines”, BCN, 2011
- 2011 and 2012 edition of CEABOT, Sevilla and Vigo
- International Conference on Computer Vision ICCV 2011, Barcelona
- MIPICV Industry Day, Barcelona
- Numerous guided visits to IRI
In order to let people know in a more effective and easy way all our activities, we have decided to be part of the main social networks. Starting in 2011, we maintain Twitter and Facebook accounts as well as a YouTube channel.

We use our Twitter account to publish our job offers, to inform about the celebration of our research seminars, and to announce all the international visitors we receive. We also inform about our attendance to different outreach events. Our Facebook account is used to publish images and answer questions and comments from many users.

YouTube is mainly used by our researchers, to share videos of their demonstrations and work.

@IRI_robotics
facebook.com/institutderobotica
youtube.com/institutderobotica

During the years 2011 and 2012, 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 research to the public.

54 newspapers
mentioned IRI in 2011-2012
El País, El Mundo, ABC, ARA, La Razón, La Vanguardia, ...

19 television programmes
mentioned IRI or interviewed IRI members in 2011-2012
TVE1, TVE2, TV3, Telecinco, BTV, ...

10 radio programmes
mentioned IRI or interviewed IRI members in 2011-2012
CatalunyaRàdio, RAC1, COMRàdio,
**Funding**

*Budget*

Data for the year 2012

Total: ~3 Millions €

- UPC General Budget: 17%
- CSIC General Budget: 29%
- Competitive Personnel Programs: 17%
- Competitive Project Funds: 37%
- Self-funding percentage: 54%

*Expenses*

Data for the year 2012

Total: ~3 Millions €

- Personnel: 84%
- Overheads: 3%
- Scientific equipment: 7%
- General running expenses: 4%
- Other project related expenses: 2%
Tibi at the Barcelona Robot Lab
Jordi Riera at the Fuel Cell Control Laboratory and Manipulation Laboratory
Sergi Foix with the WAM manipulator in the Perception and Manipulation Laboratory
Gonzalo Ferrer performing a demonstration with Tibi robot
Patrick Grosch assembling the Hexaglide of the Kinematics Laboratory.

Assembling a hexapod in the Kinematics and Robot Design laboratory.

Tibi and Dabo robots to the Barcelona Robot Lab. From left to right: (1) Federico Thomas, (2) Aleix Rull, Andreas Allué, María Laura Sarmiento and Gabriela Cembrano.

Testing the Kinton quadrotor at the FME building grass. From left to right: (1) Mateo Gil, (2) Adrián Llopart, Montserrat Manubens, Josep Maria Porta, (3) Sergio Guerra, (4) Juan Andrade, Montserrat Manubens, Josep Maria Porta, (5) Sergio Guerra, (6) Juan Andrade, Montserrat Manubens, Josep Maria Porta, (7) Sergio Guerra, (8) Juan Andrade, Montserrat Manubens, Josep Maria Porta, (9) Sergio Guerra, (10) Juan Andrade, Montserrat Manubens, Josep Maria Porta, (11) Sergio Guerra, (12) Juan Andrade.

Mobil Robots Laboratory.
Nàdia Tolós, Adrián Llopart and Sara Argerich in CEABOT 2011.

Nàdia Tolós, Susana Pons and Sandra Troyano in AESSBOT’11.

Anaís Garrell with RAC1 Radio (Saló del Còmic 2012).

Guillem Alenyà shows the humanoid robots to some kids in the IRI stand of the Saló del Còmic 2012.

Darwin follows in a line in the 800 stand of the Saló del Còmic 2012.

Federico Thomas, Gonzalo Ferrer, Joan Pérez, Alberto Sanfeliu in the program tres14 (TVE2).

Attila Husar and Cristian Kunusch with a segway powered by fuel cells (work by Eduard Castañeda and Enric Asunció).

Attila Husar and Cristian Kunusch with a segway powered by fuel cells (work by Eduard Castañeda and Enric Asunció).

Another humanoid project co-developed with the Campus Party (TVE1).

Guided visit to Fuel Cell Control Lab with Stephan Strahl.

Workshop on “Introduction to humanoid robotics” held in the stand of Saló del Còmic 2012.

Stephan Strahl, Attila Husar, Carlos Ocampo, Cristian Kunusch and Jakob Illera.

Photo of Perception and Manipulation Group (30-January-2012). 

Photo of Automatic Control Group (30-January-2012).

Photo of Automatic Control Group (30-January-2012).

View of Automatic Control Group (30-January-2012).

Method Control Systems Laboratory.

Workshop.

EIC Semantic Epistles.

Eugenio Espanó, Lluís Alcaraz, Roberto Colombo and Cecilia Cortés Constituted by the Administrative Team.

Photo credits: Ernesto Teniente, Ivan Huerta and Alberto Sanfeliu P., Miquel Torró, Martí Morta and Teo - Front line: Alberto Sanfeliu, Tibi, Edmundo Guerra, Juan Andrade and Oriol Bohigas.

- Second line: Rubén Vaca, Enric Celaya, Vicente Ruiz de Angulo and Attila Husar.

- Third line: Carlos Ocampo, Daniel Rehmbock, José Sánchez, and Attila Husar.

- Second Line: Vicenç Puig, Mauricio Primucci, Juan Manuel Allué, María Laura Sarmiento and Gabriela Cembrano.

- Third line: Carlos Ocampo, Daniel Rehmbock, Joël Giraudet, Tor Cerniers, Cristian Kunusch and Jakob Illera.

- Fourth line: Carmen Gaspar, in the Fuel Cell Control Laboratory.

- Computer-Supported Learning solutions for improving spatial applications can be applied to a wide range of problems, such as automatic detection of people, panoramic odometry, medical imaging and 3D virtual environments.

- The robotic arm performs the task of closing the board.

- Mobile robots mapping on 801-art.

- A parallel-cable driven hexapod for pincel-manipulation tasks.

- Wünderlich’s kinematotropic linkage, with dimension changes in its C-space.

- Mobile robotics in the Autonomous Laboratory, with BTV.

- Party planning and manipulation.

- A parallel-cable driven hexapod for pincel-manipulation tasks.

- A parallel-cable driven hexapod for pincel-manipulation tasks.

- Mobile robots mapping on 801-art.

- A parallel-cable driven hexapod for pincel-manipulation tasks.

- A parallel-cable driven hexapod for pincel-manipulation tasks.