The *Institut de Robòtica i Informàtica Industrial* is a Joint University Research Institute participated by the Spanish National Research Council and the Universitat Politècnica de Catalunya. Founded in 1995, its scientists have addressed over the years many research topics spanning from robot kinematics, to computer graphics, automatic control, energy systems, and human-robot interaction, among others. This book, prepared for its 25th anniversary, covers its evolution over the years, and serves as a mean of appreciation to the many students, administrative personnel, research engineers, or scientists that have formed part of it.

CSIC

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

History of the Institut de Robòtica i Informàtica Industrial

Pablo Jiménez Schlegl

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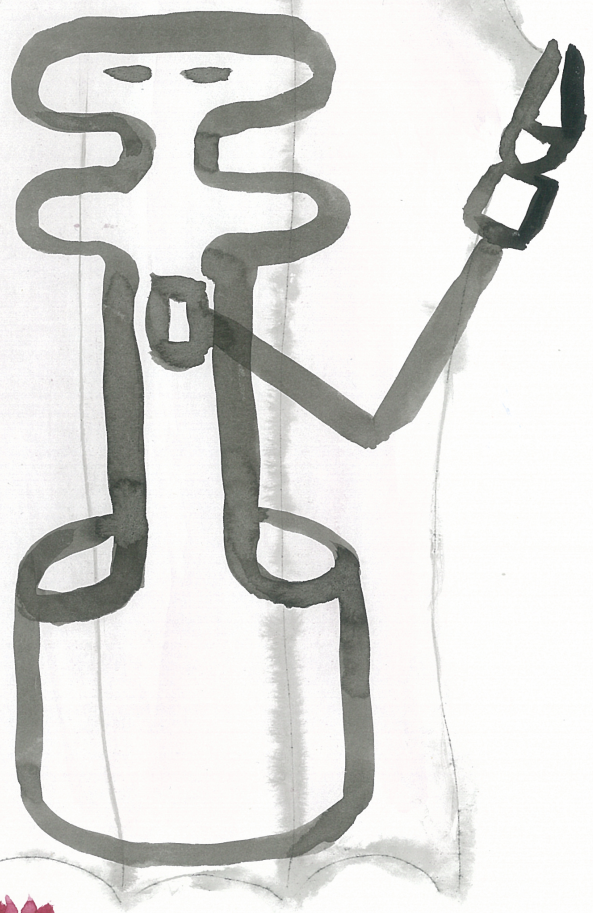

Pablo Jiménez Schlegl is an Associate Researcher at IRI. He has been at IRI since its foundation and is one of the few people that have witnessed most of the anecdotes included in this book.

Institut de Robòtica i Informàtica Industrial

1995-2021

HISTORY OF THE INSTITUT DE ROBÒTICA I INFORMÀTICA INDUSTRIAL

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Cover art: fragment of the Sumi-e dyptic entitled “Sumiè Robots. Sumiè Clothilde”

"Research is formalized curiosity. It is poking and prying with a purpose".

Zora Neale Hurston

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PREFACE

When looking back at the history of our institute, one cannot but smile at the illusion and push that has driven its creation and development along the years. It is not a grin of sufficiency, a smirk of us old dogs about the naivety of the younger ourselves (or not only), but mainly an involuntary smile on the accomplishments and feats that have been performed by this permeable collective of persons along the years: “Wow, we’ve done a lot of things!”. This report on the first 25 years of IRI does not pretend to be just an account of such accomplishments, many of which surely have been omitted, but also to tell the story of the main value of the institute, namely the people. So, together with the description of the physical growth of IRI as for premises and equipment, the institutional highlights, and the scientific exploits, the aim is also to capture the chatter at the coffee machine, the jokes before and during the reunions, the small talk in the common spaces, the cursing of the printer when it has run out of ink or there is paper stuck, the watering of the plants, or the comparison of cooking procedures during the dinner pause. Not explicitly, of course, there is no register of this, but through the social events and initiatives that have taken place along these years.

The main body of this book is divided into five periods. They are not evenly distributed, as for the corresponding duration: the first, second and fifth span 5 years each, but the third and fourth are 4 and 7 years long, respectively. The reason for this has to be sought in the main events that characterize each period: the changes from one period to the next may be about the physical location or expansion of our premises, or be of organizational nature. Within

each period, an account on premises and equipment, research and education (including also technological transfer and outreach), personnel, and social life has been performed, but again for the same reason, not always in the same order, and sometimes combining some of these topics.

I have tried to be balanced as for the space devoted to each of the current research groups. Each one has its own idiosyncrasy, and by the very nature of their topics, in some cases there was more available graphical material than in others. I am quite conscious that there may be omissions, but I hope they are reduced to a minimum after having asked the doctors and some of the support staff to revise the text. Information sources, besides my own frail memory and some informal conversations with colleagues, have been the biennial IRI memories and the Board meeting minutes (in some cases, very old e-mails have also been helpful). I am very grateful to the detailed feedback I have become from Carme Torras and from Juan Andrade, who has also provided valuable graphical material, as have done Lluís Ros, Tom Creemers, Víctor Vílchez and Patrick Grosch. Anaís Morales did great work in the layout of the first version of the book, and Juan Andrade helped me a lot in shaping this final version (thanks also for the back cover text and the biographical note). Maria Alberich has provided her talent for the marvelous cover art, and the cover design is work of Víctor Vílchez. I would like to thank warmly the support provided by the administrative staff and the project support and outreach office and of course also to my colleagues in the 25th anniversary commission. All of them have contributed to make a better account of our history, while for all the errors and omissions I take the sole responsibility.

Pablo Jiménez Schlegl
May 2022

CHAPTER 1 - 1995-2000

THE BEGINNINGS: IRI AT THE NEXUS BUILDING

Foundation, origins, and initial organization

The *Institut de Robòtica i Informàtica Industrial* was officially given birth towards the end of 1995, when on November 25th José María Mato de la Paz, President of the Spanish Research Council, and Jaume Pagès Fita, Rector of the Technical University of Catalonia, signed its foundational document. It had its roots in a previous research facility, the *Institut de Cibernètica*, which had been founded by the former Rector Gabriel Ferraté some 20 years before, and which split into IRI, the *Institut d'Organització i Control* and the *Centre de Recerca en Enginyeria Biomèdica*. Thus, although other researchers, mainly from UPC's Automatic Control and Computer Science departments, joined the newly created institute, most of its individuals carried in their mental baggage memories about the extinct IC: their former colleagues, the premises in the second floor of the Escola Tècnica Superior d'Enginyers Industrials de Barcelona, and the equipment such as an Unimation Puma, the first contact with a real robot for many

of us; or an old analogue computer, which when donated to a museum, part of the exterior wall of the building had to be dismantled to allow its extraction with a crane.

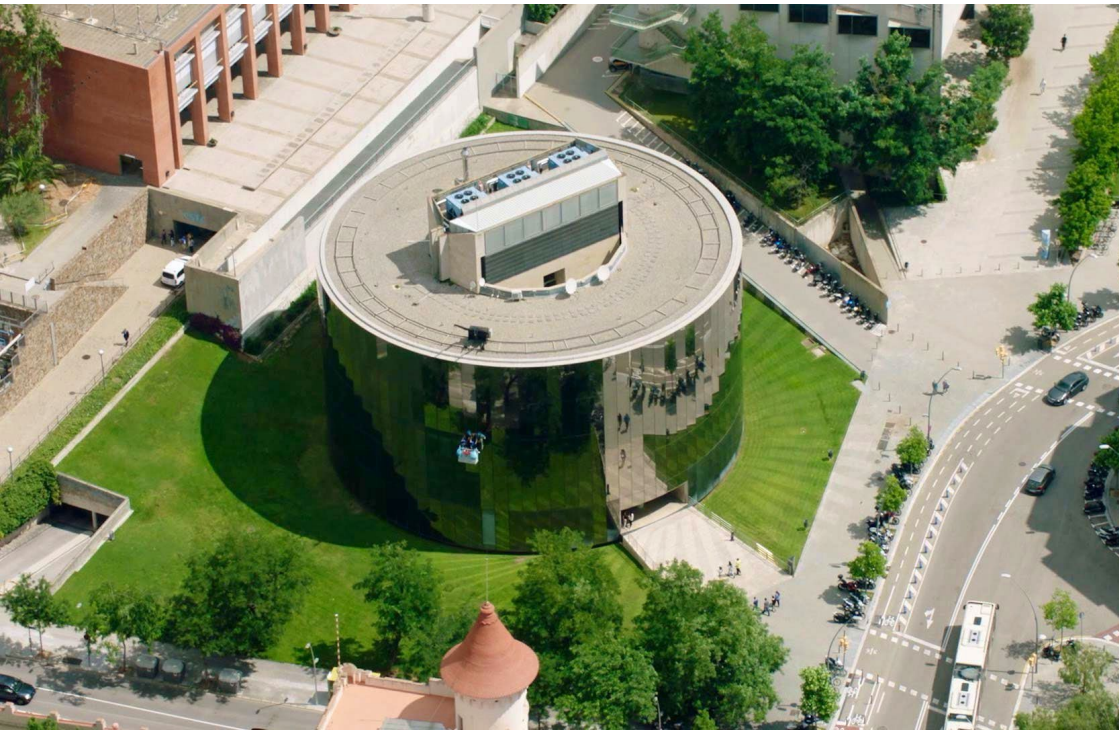
The first IRI director was Prof. Rafael Huber, and there was a steering committee formed by Prof. Carme Torras, Prof. Rafael

To understand where we were coming from: In the top left, a common student's office at IC. Notice something strange? Yes, no computers on our desks! They were all located in a common room, the Sun Workstations and the VAX terminals, in the top right. In the bottom left, our Unimation robot arm. And on the bottom right, this is how the main gallery looked like.

Huber, Prof. Josep Amat, and Prof. Pere Brunet, called IRI-Four. From the research point of view, there were three main lines: Robotics, Automatic Control, and Computer Graphics. Although each group pursued its own research topics, sometimes inter-group collaboration arose around specific projects.

Premises and support personnel

By the end of 1996, books, personalia, and some computers were packed and shipped towards IRI's new location: the second floor



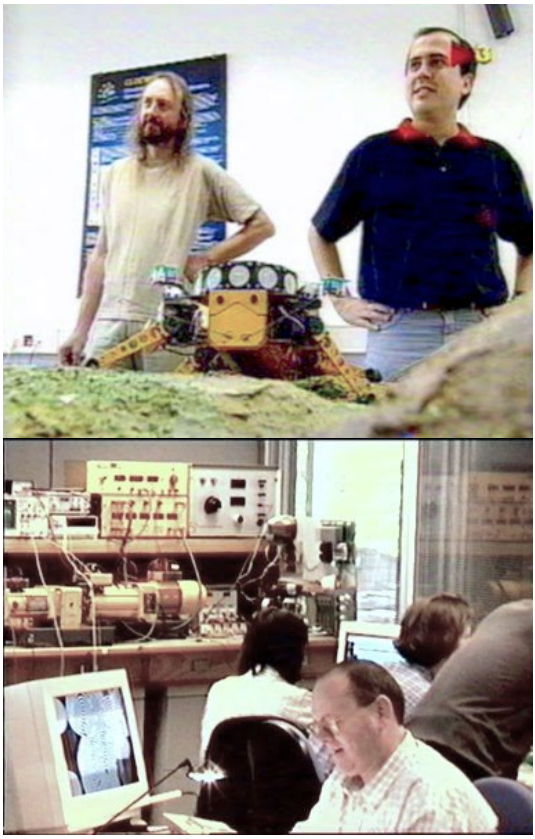
Aerial view of the NEXUS I building and its surroundings (Photo courtesy of CZFB).

of the recently finished NEXUS I building, owned by the *Consorci de la Zona Franca*, and therefore a monthly rent had to be paid. The modern, cylindrical, all dark-glass façade building is located in UPC's Campus Nord, between the military headquarters of El Bruc - aesthetically recalling a kind of shabby version of Disneyland's Castle, and those of us arriving soon enough in the morning were greeted with the reveille trumpet of the quarters- and UPC's central library, bearing the name of the former rector and founder of IC Gabriel Ferraté, so the connection with the past remained in our vicinity. Talking about neighbors, we shared floor with, and provided administrative services to, the *Institut d'Estudis Espacials de Catalunya*, Catalonia's principal space research institution, who are still in that location.

The façade of the Nexus building mirrors our surroundings. Inside, the carpet in the 8-person offices was quite comfortable for injured students.

The curved main gallery in fact vaguely recalled that of a spaceship, although the doors didn't open automatically with a whiff. The gallery was sometimes traversed by a growling colleague, thinking himself of as a kind

of tyrannosaurus rex. On the inner side of the gallery there was the computer centre, managed very competently by Blanca Ortiz, who also introduced the convention of naming the computers after more or less known musical composers. Not so long ago, our main Sun server was still named Haydn, with a backup of Sibelius... It was towards the end of this period, in 1999, when José Luís Roncero was incorporated to the computer centre staff, still under supervision of Blanca Ortiz. He was to become the patient helper and rescuer in all of our trouble with the PCs. There was also the laboratory, which was equipped with a bench of electric motor converters on which control modes and algorithms were tested, as well as our first robots, a small Zebra Zero arm, and some years later the small six-legged insect-like robot Genghis. A mock-up of rough terrain was constructed for Genghis, a platform to implement Rodney Brooks 'behavior-based subsumption



Genghis crawling happily around its rough terrain mock-up. Behind Genghis, Enric Celaya and Josep Maria Porta. In the bottom, the laboratories hosting the electric motor control equipment. Closer to the camera objective, the late Angel Gimeno.

architecture for robot control. Genghis had just 12 degrees of freedom (two per leg), but honored its name with its insect-like determination to conquer new terrain. On the outer side of the gallery were our offices, which had thus a lot of daylight, dimmed by the dark plastic covering of the glass façade, and views on the surroundings, which could sometimes be quite distracting: the meadows around the building became populated in the spring by hormone-driven students, whose mating behavior converted us in involuntary voyeurs. A nearby bike-parking made us also testimonies of a stealing attempt, aborted by some colleagues rapidly running outside and engaging a moral discussion with the robbers.

IRI's premises hosted from the very beginnings the CEA (*Comité Español de Automática*), organization at which Rafael Huber was the Secretary until 2005 and later Alberto Sanfeliu, who has been very active in CEA's working group on robotics, GTRob. The link to CEA is still quite alive nowadays, with Ramón Costa also occupying the Secretary position and Carlos Ocampo as one of the chairpersons. Speaking of administrative services, our staff was composed by Yolanda Muro as administrative head, some years later replaced by Eugènia Bretones, and Rosor Sánchez, who had been Secretary at the CSIC Delegation, Roser Poblet, Immaculada Betoret, Cristina Carbajo, Lucía Moreno, and Carme Macías. Our link to the UPC library was first Montse Salazar, and later Carme Galve and Francesc Carnerero.

Scientific groups

The Automatic Control group was initially led by Rafael Huber, who, together with Antoni Guasch, worked on complex systems

modeling and simulation. Jordi Riera's research interests split between control of electric motors,(he and his students were the ones playing with the aforementioned motor bench) and the control of complex distribution systems, together with Tom Creemers, who applied his expertise in constraint logic programming. Water distribution and sewage systems was the main research topic of Gabriela Cembrano.

The occupants of office #7, standing from left to right, Tom Creemers, Josep Maria Porta, Montserrat Mata, Pablo Jiménez, Albert Castellet, Judit Martínez, and Miquel Sainz. Front row, a fake Lluís Ros (the original was in a stage abroad), and systems manager Blanca Ortiz.

The Robotics group leader was Carme Torras, being neural networks, heuristic search and collision detection some of her research interests. By then, she was directing the theses of Vicente Ruiz (who defended his PhD thesis on catastrophic interference in neural networks in 1996, at the University of the Basque Country) and Pablo Jiménez (in heuristic search and collision detection), among others. Two of her former PhD students, Federico Thomas and Enric Celaya, now CSIC researchers, were conducting their own topics: FT in computer vision (directing Judit Martínez), robot kinematics (directing Lluís Ros and Albert Castellet), and collision detection, and EC on walking robots control architectures (directing Josep Maria Porta). In the years to come Federico would play and increasingly relevant role in the international kinematics scene,

mainly through his involvement in IFToMM (International Federation for the Promotion of Mechanism and Machine Science) and the ARK (Advances in Robot Kinematics) symposia. Alberto Sanfeliu, who had been partial time professor at the UPC and owned a private company on computer vision, and had also been one of the founders of the AERFAI, the Spanish Association for Pattern Recognition and Image Analysis, which he chaired from 1991 to 2000, became full professor of Computational Sciences and Artificial Intelligence at UPC and founded the Artificial Vision and Intelligent System Group (VIS), also at the UPC. His PhD students included Juan Andrade (SLAM) and Francesc Moreno (visual tracking).

As for the Computer Graphics group, led by Pere Brunet, with Isabel Navazo, Alvar Vinacua, Marta Fairén, Jordi Moyés, Antoni Chica and Eva Monclús as the main team members, they were working mainly on virtual reality and on modeling and visualization of soft tissues and organs of the human body, from sources gathered from medical imaging techniques such as computer tomography. The latter allowed some years afterwards to engage a project, together with the Automatic Control Department and the Hospital Vall d'Hebron, on what is nowadays known as robot assisted surgery. A different but also quite interesting field pursued by this group was architectural visualization, which among others focused on ancient cultural heritage sites, allowing the user to visit them virtually.

It was during this period when the first IRI's UPC PhD dissertations were defended (specifically in 1998): Pablo Jiménez Schlegl (nowadays Department Head, at IRI's Board), Albert Castellet Llerena, and Judit Martínez Bauzà, the first one directed by Carme Torras, and the other two by Federico Thomas. A

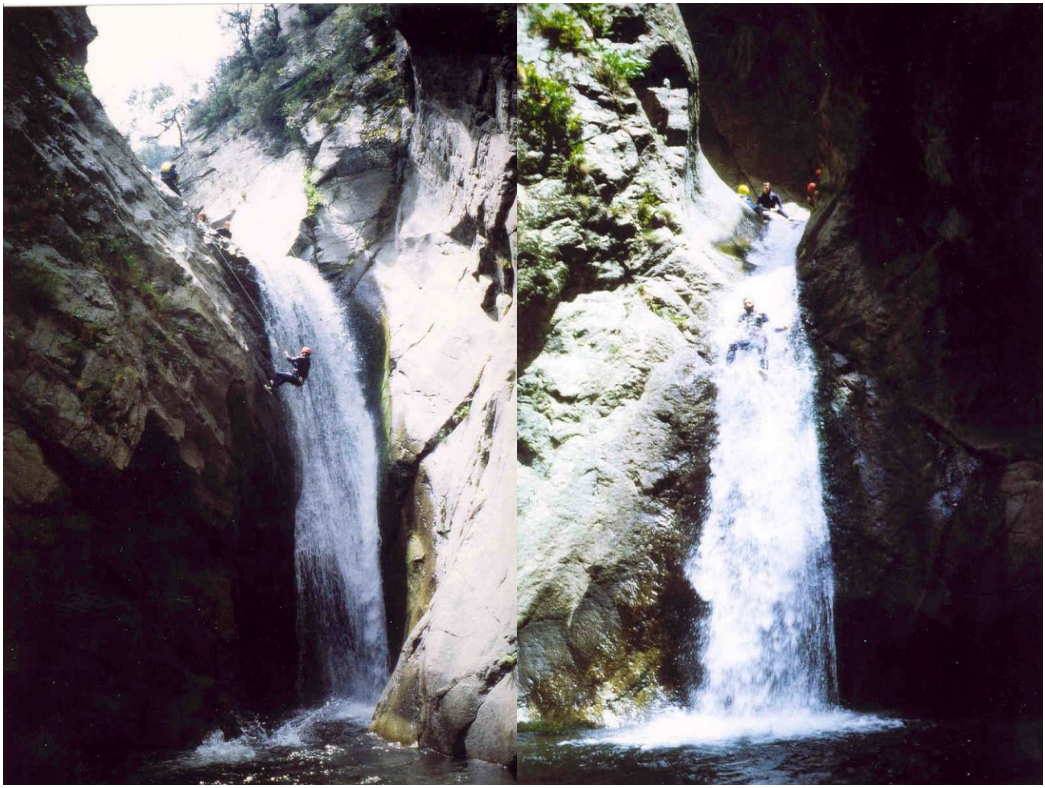
complete list of PhD thesis carried out at IRI can be found in Appendix A.

Social life

To enforce the social bonds between IRI members, an annual dinner before Christmas was held. On one of such occasions, in a small restaurant in Sant Gervasi, a spectacle was included: the fight between the chef and the maître about the number of preordered roasted duck dishes, which nevertheless and despite shouts and knife wielding ended without bloodshed, except for the ducks. Another year, financial shortage was the reason to celebrate the dinner just three floors below our workplaces, at the Nexus building's basement cafeteria. Despite the modest setting, the dinner was funny and enjoyable. Social bonds were also

tightened by outdoor activities: one year a group of IRI members, led by two expert climbers as Albert Castellet and Lluís Ros,

dared to initiate in canyoning at the river Llech in North Catalonia a whole group of mountain sports freshmen, with just a previous accelerated course on rappelling. Director Rafael Huber and his two daughters also participated in the adventure, which concluded without remarkable injuries.



IRI's canyoning experience.
Who said that research was not adventurous?

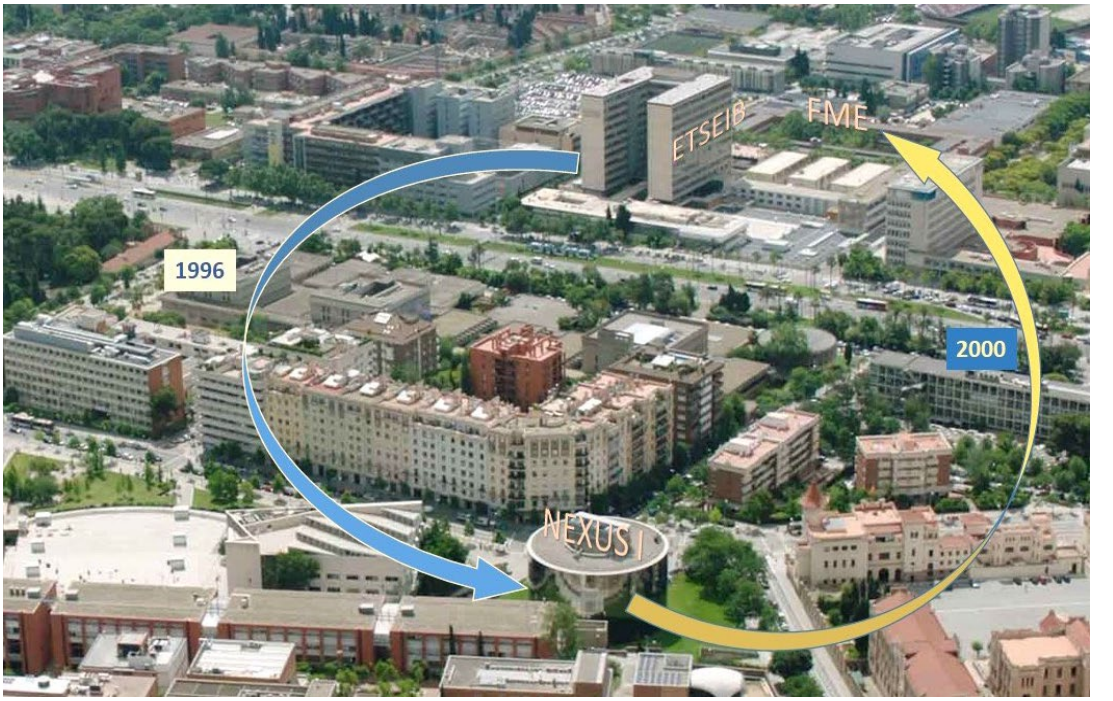
CHAPTER 2 - 2001-2005

THE FIRST YEARS IN THE *PARC TECNOLÒGIC*

Premises and equipment

With the advent of the new century and millennium, and once proven that there was life beyond the 2k year bug, it was also time to move to a new location. IRI had been growing in personnel, place had become scarce, and the monthly rent was also unsustainable for our modest budget. Fortunately, the "U" building in UPC's Campus Sud had undergone a topological transformation, becoming an "O" thanks to the addenda of a whole new wing, on its south side, which was going to host the new *Parc Tecnològic de Barcelona,* initially called *Parc Tecnològic de Pedralbes Sud*. This technological park was to house Centre CIM, Virtual Reality Centre (CRV, which later became part of ViRVIG), Centre for Industrial Equipment Design (CDEI), and ourselves. A collaboration agreement between UPC and CSIC signed in March 2001, of co-financing at 50% terms the construction and equipment of IRI's new headquarters, allowed to fulfill this need, which meant 540 m^2 of useful surface area plus 135 m^2 of common spaces.

Boxes were packed again (in fact, some of them had remained unpacked...) and once more we crossed Barcelona's Diagonal Avenue to the new premises, in the same building that hosts the Faculty of Mathematics and Statistics. The *Parc Tecnològic* was officially inaugurated on October 16th, 2001 by the former Catalan President Jordi Pujol, the Catalan government minister for Universities, Research and the Information Society Andreu



Schematic representation of the two main moving operations experienced by IRI.

Mas-Colell, and the Spanish minister of Science and Technology Anna Birulés, together with the UPC rector Jaume Pagès and other academic and scientific personalities, when our institute had already attained cruise speed in its functioning some months ago. By then, we had one single laboratory for the whole institute, which also hosted our modest library, at the second floor.

Two frames from the *Trasllat-Cam* which captured the moving. Top: Lluís Ros with two aliens that some years later were donated to the science fiction section of UPC's Library. Bottom: Josep Maria Porta, Eugènia Bretones, and José Luís Roncero.

Some words have to be said about our surroundings. We are in the middle of a university zone, somehow in the frontier between UPC and the University of Barcelona (UB). This means that we are surrounded (and in fact also within) faculties and some university service buildings (more than a decade ago there was the cafeteria or canteen, and recently a students' residence has been built). On the north side of the building there is a shadowy street with tall plane trees (*Platanus acerifolia, hispanica or hybrida*), which are also present inside

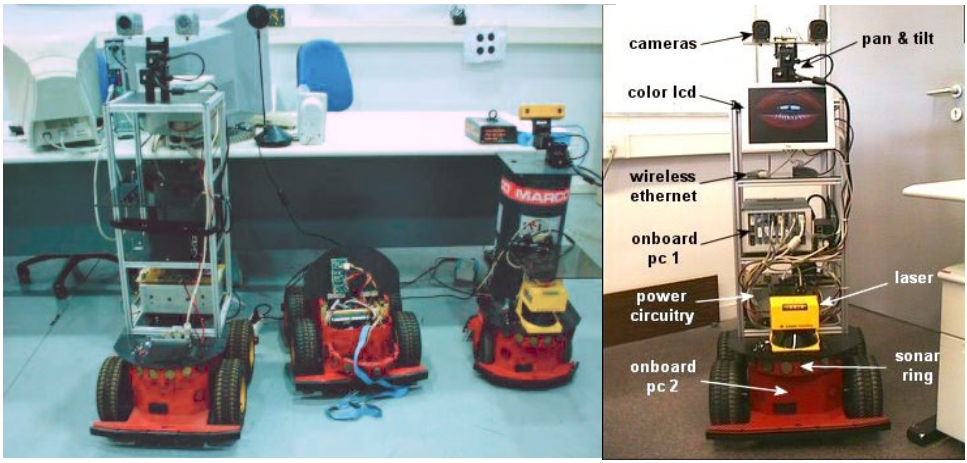
the faculty's court. On the south side there is an open ground serving as parking lot. After a rainy day always a large "lake" appears, increasing the challenge level of safely parking attempts. Further away, but still quite close, the football stadium of FC

Inauguration of the *Parc Tecnològic* in 2001. From left to right, Prof. Josep Amat, our Director Rafael Huber, MHC Andreu Mas-Colell, MHP Jordi Pujol, and Minister Anna Birulés.

Barcelona appears in sight, and behind the silhouette of the hill of Montjuïc. The absence of residential and commercial zones has attracted other kinds of transactions: during the night and sometimes even in the early morning transvestite prostitutes offer

their services with deep, intimidating voices. The streets are relatively quiet, only when there is a football match in the stadium, chaos reigns all over the quarter, and finding an empty spot for parking becomes mission impossible, even in the first hours of the morning.

An agreement between UPC and CSIC, signed by Josep Ferrer Llop as Rector of the UPC and Carlos Martínez Alonso as President of the CSIC on October 1st, 2004, paved the way to expand the premises with additional space at floor level -1 (224 m^2). However, these spaces were not effectively transferred to IRI that year nor the following ones. Instead, we were already using two smaller spaces at this floor level, situation which was regularized by an agreement in 2007, as explained later. The first of this spaces (50.63 m^2) hosted both the wheeled and the legged mobile robots. As for the first, they consisted of three four-wheeled Pioneer 2DX robots, and two two-wheeled Segway. Two stereo vision heads, EVI 370 Sony cameras, GPS sensors,



The robots ANNA, HELENA and MARCO at different stages of construction. Full equipped robot ANNA.

compasses, and a Leuze laser range sensor were mounted on two of the Pioneer platforms, which became our first wheeled robots with a given name: MARCO and ANNA. Also the third Pioneer platform received a name, HELENA, without any apparent relation to Homer's Iliad.

Enric Celaya explaining the behavior-based control architecture on the LAURON III robot to President Zapatero and Pedro Duque (who years later would become Minister of Science and Innovation).

The lab was shared by both robotics and automatic control groups, serving as improvised workshop in which Guillem Alenyà worked on the legged robot ARGOS or to hold the electric motor control bench. Below, the Zebra Zero robot equipped with a force/torque sensor which allowed to perform compliant insertions, and the tactile table designed at IRI.

Alberto Sanfeliu, Juan Andrade, Francesc Moreno, and their students used them as experimental platforms to conduct their research on SLAM, tracking and sensor fusion. Regarding legged robots, Genghis was still allowed some frolicking on its terrain mock-up, mainly for demos, but larger platforms were necessary. First, ARGOS was constructed, also a six-legged walking robot,

in collaboration with other university departments, as a proof of concept. Some difficulties were encountered in its functioning, and for the sake of efficiency a more sophisticated robot (18 dof and also 18 kg in weight), LAURON III, was acquired from the *Forschungszentrum Informatik Karlsruhe* (FZI) in Germany. Its three-axes force sensors at each foot, together with its modular reactive control architecture, allowed the robot to walk on real rough terrain, as experimented in the building's garden. Enric Celaya, together with his student José Luís Albarral, used LAURON for testing their research in natural landmark detection, in the national project SIRVENT (2003-06). LAURON even appeared in the press, together with former President Zapatero and the Spanish astronaut Pedro Duque.

Also on floor level -1, in one of the offices some years later successively occupied by Federico Thomas and Juan Andrade, an embryonic Fuel Cells Lab was created. This was an endeavor carried out by Jordi Riera, now head of the Automatic Control Group, together with Miguel Allué (he joined IRI on January 2004, and he would stay at IRI until April 2016), and later Attila Husar (who entered in February 2006) and Maria Serra (she joined the institute in November 2006). The aim was to evaluate the operational parameters so as to obtain an optimal performance under different conditions for different families of fuel cells.

In April 2004 two industrial Stäubli Unimation RX60 robot arms were acquired, thanks to the regional project CERTAP: *Estació de treball multibraç*, led by Federico Thomas (CERTAP was a network of technological resources which some years later became XaRTAP), and were mounted in the large laboratory on floor 2, close enough to each other so they could be engaged in collaborative tasks, such as making a toast. A structure was built

around that allowed to mount overview cameras and security barriers, to power off the robots if someone invaded the restricted area.

Robotic cell with the two Staübli manipulators.

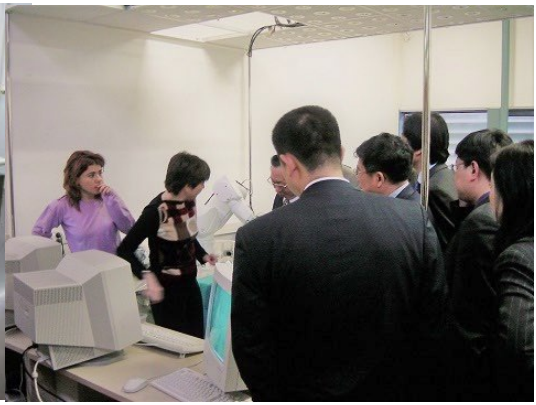
As for the bench of electric motor converters, by the end of 2004 still a demo involving them was performed, but it was dismantled shortly after and the motors transferred to ETSEIB. The

laboratory was further equipped with the veteran Zebra Zero, and during the forthcoming months also with a 6 degree of freedom haptic display based on a delta parallel robotic architecture, a tactile table for robotic assembly tasks (which was designed at IRI and constructed in collaboration with the Department of Strengths of Materials of UPC), force and torque sensors, cameras, etc. Later, in 2006, also a 3 fingered Barrett hand would be acquired. As a consequence, it made sense to rename the laboratory as the Advanced Robotic Cell Lab.

A small room besides this lab hosted another workshop (in fact, the first one we had, before the floor level -1 expansion), ruled by Angel Gimeno, until his sudden passing at the very entrance of the building. It was a shock to all of us, and his kind and helpful disposition will always be remembered by those of us who had known him (it also fostered the installation of an Automated External Defibrillator at the building's main entrance). Later this workshop became the office of the responsible of the robotics lab. Our director at present, Guillem Alenyà, has loving memories for this space, as for some years he was precisely in charge of the laboratories and thus the dweller of this room.

Angel Gimeno in the workshop.

Already these years our Institute began to have a certain appeal as for institutional visits: impressive demos could be shown,



Setup of the robot guided surgery on a goat's skull (this project involved ESAII and IRI's groups on robotics and computer graphics). On the right, Eva Monclús and Isabel Navazo perform the demo to the Shanghai University delegation.

Left: The Shanghai University delegation visiting the Mobile Robotics Lab with Juan Andrade, Francesc Moreno and Alberto Sanfeliu. Right: The Cuban Ministry of Industry delegation, led by Fidel Castro, son of the homonymous former Cuban leader, attending to the explanations of Enric Celaya, with Director Rafael Huber and UPC Rector Josep Ferrer at the centre of the image.

which converted IRI in a must, in the visits that foreign delegations made to the UPC. Some examples include the visit of academic authorities of the University of Shanghai in March 2002, or a Delegation of the Cuban Ministry of Industry in March 2003.

Research and education

Research funds came from the Spanish national research and development plan. Additionally, our institute had always participated in projects from the European framework program since its beginnings. Such projects included PARALIN: Parallel computing modeling for industrial problems (1996-99), with Carme Torras as PI, CLOCWiSe: Constraint logic for operational control of water systems (1996-98) with Jordi Riera as PI, and PLANET 2: European network of excellence in AI planning (2001-2004) with Tom Creemers (PI). But the participation in European-wide research boosted towards 2005-2006, mainly with projects in Research and Innovation Actions and Innovation Actions in the Information and Communication Technologies area, and in other calls as well. IRI started also to have a notable presence in international academic networks such as EURON, which later (2012) originated euRobotics, together with the industrial network EUROP. It was around these years when IRI and ICARUS signed their first collaboration agreements, the company which a few years later became PAL Robotics. Collaboration with PAL Robotics is ongoing, as demonstrated by the recent incorporation of a couple of TIAGo Robots by the Perception and Manipulation group, the building of the IVO robot for the Mobile Robotics group, their joint participation in the EU

Projects SOCRATES and CANOPIES, and on the national project RAADICAL.

During that period the PhD theses of many of today's IRI seniors were defended, among others who pursued their careers abroad: Lluís Ros Giralt, Josep Maria Porta Pleite, today's head of the Kinematics and Robot Design group, our former Institute director Juan Andrade Cetto, who would receive the EURON Georges Giralt Best PhD Award in 2005, and Francesc Moreno Noguer. Again, see Appendix A for details on their and other theses.

Personnel

IRI continued to expand in personnel, both on the scientific as well as on the administrative and support sides. In May 2001 we welcomed a new Computer Centre head, José Lázaro, who is still in charge of this service nowadays. In September of 2003 Esther Expósito joined the administrative team, where she would do great work until August 2019, with the sole interruption of maternal leave.

In 2005 Eugènia Bretones ceased her activity as Administrative Officer at IRI. The new Administrative Officer, Ana Canales, displayed in the coming years unmatched levels of competence and knowledge about the functioning (and the shortcuts) of the mother institutions, a high organizational prowess, and a willingness to help which still inspires the administrative team nowadays.

Social life

The workshop at floor level 2 was not only used for research support purposes, but also for free-time handcrafting. There, we constructed, in our free time during lunch, a couple of wooden scientific toys for two colleagues that married during these years. First it was “Barra Lliure”, for Albert Castellet, which consisted in bars of different lengths, each one attached to a perforated small cube, so that any bar could go through any such a hole, and thus whole structures with some degrees of freedom could be constructed. The game was loosely related to his PhD thesis. Then it was the turn of Lluís Ros, whose present, with the name “Cubo libre”, a clear allusion to the popular mix drink of cola and rum,

Typical Nativity scene, with robots as the main characters, Christmas 2005 .

consisted in three-dimensional puzzles, in the form of wooden cubes that had to be dismantled into (or reconstructed from) their fitting parts.

The last year of this period ended not only with the traditional Christmas lunch, but also with some physical activity: on December 7th, people met at the Canal Olímpic in the nearby village of Castelldefels, to participate in archery competitions, kart races, and other playful sports that quite conveniently stimulated appetite for the subsequent lunch.

CHAPTER 3 - 2006-2009

NEW DIRECTORS AND THE RESTRUCTURING OF IRI

Organization and personnel

In 2006 Rafael Huber ended his service as director and retired shortly after. Federico Thomas who had been deputy director since October 2004 was elected director, and Jordi Riera was assigned as deputy director. He stayed in this position until the last months of Federico's mandate, when Juan Andrade replaced Jordi to allow a smooth transition to the new directive team. This change in the directive team came together with a deep organizational restructuring, according to the recently approved internal regulation: the creation of the Board, with the directive team, the administrative officer, the department heads, and representatives of the doctors, students, and personnel of support, for resolving questions about the daily functioning of the institute with monthly meetings, and the Council, which also includes all the doctors, meeting once or twice a year, addressing the whole economic and scientific functioning of IRI. The Board had its first meeting and constitution on July 21st, 2006. In March of this year

Ferran Cortés entered the general support team in the workshop, and in December Profs. René Alquézar and Maria Alberich were ascribed to IRI.

Towards 2006-07 the Computer Graphics group created their own research centre, which later became the Research Centre for Visualization, Virtual Reality and Graphics Interaction (ViRVIG). As for IRI, this meant reducing the number of departments to two: Robotics, led by Carme Torras, and Automatic Control, led by Maria Serra. Later, the minimum size requirement for CSIC's research departments forced to fuse both departments into a single one, which was structured into the four research groups at present: Automatic Control, Kinematics and Robot Design, Mobile Robotics and Intelligent Systems, and Perception and Manipulation. They were led by Jordi Riera, Federico Thomas, Alberto Sanfeliu, and Carme Torras, respectively. These groups formed by the natural clustering of research interests that had developed along the years. Which doesn't mean that they are hermetically isolated from one another: besides sharing common topics and sometimes participating in the same projects, also migrations of researchers from one group to the other have happened, as researchers evolve and the gravitational centre of their research topics does also shift with

Ferran Cortés occupied the workshop at floor level 2, before some years later the workshop at floor level -1 became operative.

time. For example, Lluís Ros had changed already as predoc from Automatic Control to Kinematics, then still forming part of the Robotics group. This group later incorporated Josep Maria Porta as a postdoc and Enric Celaya, who had been for some years in the Mobile Robotics group, as well as Vicente Ruiz de Angulo, previously working on neural networks, before the deep learning explosion. The Perception and Manipulation group, on the other hand, welcomed Francesc Moreno, previously in the Mobile Robotics group, and Júlia Borràs, who had done her PhD thesis with Federico Thomas and had stayed some years abroad. Most of these changes/incorporations happened years later to the actual formation of the groups. Turning back to this period, the professors of the former CG group finally moved to their new offices in the recently finished Omega building in the North Diagonal UPC Campus in June 2008. Despite the leaving of the CG group, towards the half of the considered historical period of 25 years, IRI had grown to around 70 people, doubling the population with respect to the beginnings.

New elections were called in 2008 and this time Alberto Sanfeliu was chosen as the new director. He appointed Juan Andrade as deputy director. In November of this same year IRI became a Joint University Research Institute (CSIC-UPC). This came together with the official act of inauguration of the Institute on November 19th 2008.

Also in 2008 our two laboratory-Sergis, for their involvement in their respective group laboratories, entered the institute: Sergi Hernández (mobile robots) in April, and Sergi Foix (perception and manipulation) in September. The very same year Léonard Jaillet joined the Kinematics and Robot Design group as a

postdoc researcher, contributing until 2012 in the design of algorithmic tools to plan motions of complex mechanisms.

In 2009 Vicenç Puig was formally ascribed to IRI. He was well-known by some of us, from the time he was coordinator of the master program of ESAII and some of us were teaching courses in this program. Later he became department head of ESAII for some years. He joined the Automatic Control group, providing his know-how about different topics in control, mainly in fault-tolerant control. In March, José Luís Rivero joined IRI as general support, but his main contribution, until he left in 2013, was the construction of IRI's website and intranet. During that very same year, the computer centre staff was enriched by the incorporation of Evili del Río in July, and the administration staff by the addition of two new members, César González in October, and Eduardo Ballesteros in November.

Research and education

As mentioned before, the growth in personnel also came with an increase in European projects: towards the end of 2005 began NRS: Research atelier network on robot systems (2005-2006), led by Alberto Sanfeliu, and in February 2006 started PACOPLUS: Perception, action & cognition through learning of object-action complexes (2006-2010), with Carme Torras as the PI at IRI. This project would have a continuity with IntellAct, and Alejandro Agostini, a PhD student of Enric Celaya, contributed significantly with his research topic on reinforcement learning. The end of this same year witnessed the kick-off of URUS: Ubiquitous networking robotics in urban settings (2006-2009), led again by Alberto Sanfeliu. In this project participated, among others,

Viorela Ila, who was going to stay at IRI from 2007 until 2009, first as research assistant and later on as research scientist with a Juan de la Cierva grant.

Meanwhile, the bonds with external institutions continued to flourish. As an example, since the creation of CETAQUA (Technological Centre of Water) in 2006, a private foundation for research and development in water management, participated by Aigües de Barcelona, the main water supplier of the city, the UPC and CSIC, Gabriela Cembrano had collaborated actively with this institution in the topic of management and resilience of critical infrastructures (and still does).

In October 2007 our current director, Guillem Alenyà Ribas, presented his PhD thesis. The last year of the decade witnessed also the start of the Humanoid Lab project (2009-2012). This

Some of the tuned Robonova humanoids. Notice the camera head of the robot to the right. On the right, the winning IRI team of the 2016 CEABOT edition, with Laia Freixas and Alejandro Suárez, as well as two high school students, coordinated by Gerard Canal, showing the Bioloid robot Dexter.

UPC project meant consolidating and formalizing the initiative of using small humanoid robotic platforms "to introduce engineering and mathematics students to the robotics world." The two platforms used were the Robonova (16dof) and the Bioloid (18dof) humanoids, and most of the work with students consisted in overcoming the robots' limitations, with interventions both in hardware and in control software. This allowed to form competitive and successful teams both in national (CEABOT) as well as international (RoboCup) robotic competitions well beyond the official end of the project.

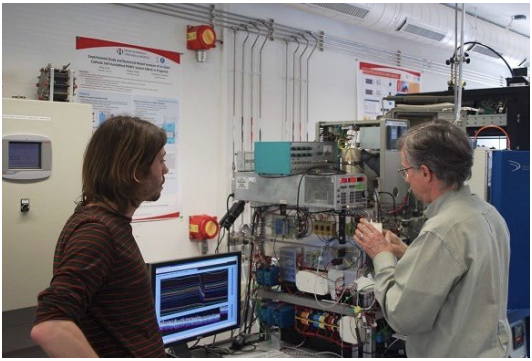
With the not so remote aim of enabling robots to be programmed one day by non-experts, we began also to focus on the topic of learning from demonstration in the group of Perception and Manipulation, with the work of Leonel Rozo, a PhD student of

The teacher feels the forces and torques sensed by the force/torque sensor at the robot's wrist while teleoperating the manipulator with the Delta Haptic Display.

Pablo Jiménez and Carme Torras, who put at use the Delta haptic device in a teleoperation setting of the Stäubli robot to learn force-based skills.

Premises and equipment

In December 2007 a new agreement between UPC and CSIC allowed for more space in floor level 2, occupying the whole south wing in this floor, in exchange of some space in the ground floor. This meant not only new offices, but moving the Fuel Cell Lab to its current location in the second floor. The testbed for small and medium power fuel cells included temperature, pressure, differential pressure, mass flow, current and voltage sensors, with real-time control, as well as a monitoring system. As for the studied PEM (Protonic Exchange Membranes) fuel cells, there was a single 2 W cell, a 7 cells stack with a total power of 120 W, a 20-cells stack with 500 W total power and a 1.2 KW cell with integrated controller and monitoring system. The presence and use of actual cells involved the installation of hydrogen and oxygen supplies to comply to the security standards for this type of equipment. The lab was soon fully operative, and

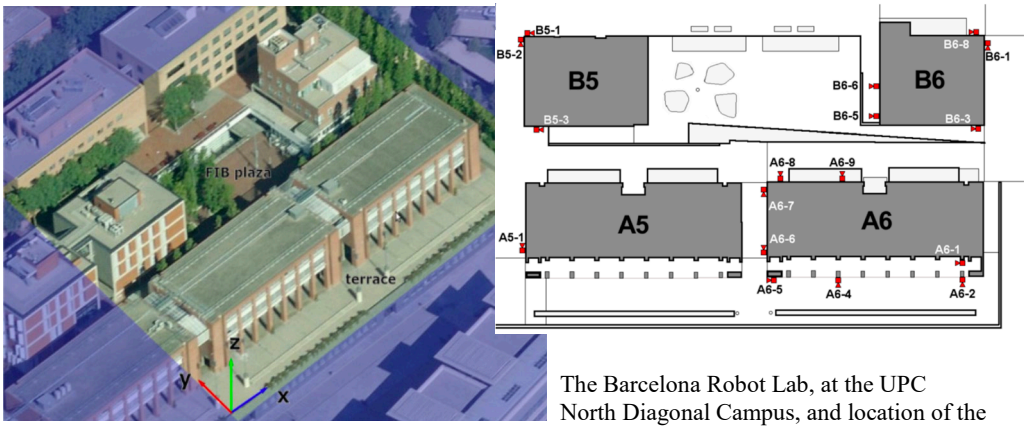


Miguel Allué and Jordi Riera with the equipment that measures via macroscopic variables phenomena that happen at molecular scale. Observe the pipelines supplying gases.

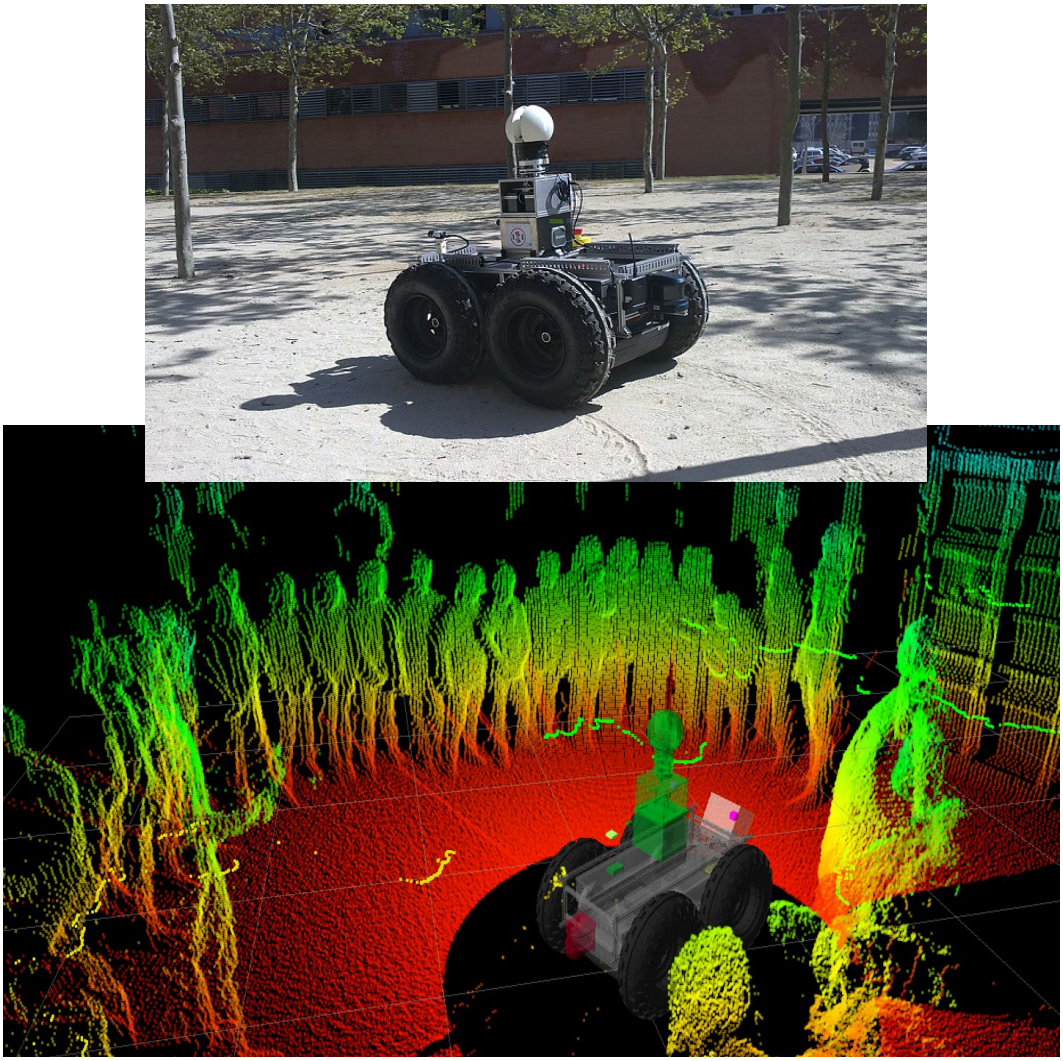
the research carried out so successful that few years later foreign students came to do their PhD dissertation with the group on this topic. Other notorious alumni from this lab include some of the founders of Wallbox, the electric vehicle charging and energy management provider.

On the Robotics side, a Barrett WAM robot was purchased in 2007 and integrated in the Advanced Robotic Cell Lab. This robot, and a few years later also its sibling, introduced whole new possibilities as for compliance and admittance control. At some point they received the names of Estirabot and Zyonz.

In 2008 the Barcelona Robot Lab was created, a wide sensorized area in the North Diagonal Campus of UPC, an open space between buildings and places with trees and a cafeteria, thus with an important presence of students, professors and other personnel of UPC, to experiment on outdoor navigation and HRI with



The Barcelona Robot Lab, at the UPC North Diagonal Campus, and location of the cameras.



TEO on an outdoors strolling, leaving its tire tracks on the ground. Below, capturing with its 3D scanner snapshot of a group of amused children visiting the lab.

mobile robots. The main challenge but also advantage of such a setting is the much larger amount of uncertainty inherent to it, as

compared with conventional laboratory environments: the unexpected may happen at any moment, taking new surprising forms.

As for our robot chaps, the Mobile Robotics group acquired and tuned TEO, a Segway RMP 400 based robot, which was to be used in the forthcoming national DPI project PAU (2009-2011), followed by PAU+, both led by Juan Andrade for real-time outdoor SLAM.

Social life

On the social side, we can stress that the summer and/or Christmas lunch had acquired a new dimension, for having a cultural visit/excursion associated to it. For example, the winter lunch of 2007 consisted in a visit to the ecological wine cellars of Albet i Noya in the Alt Penedès, including wine tasting and a *calçotada* in a nearby restaurant afterwards.

One year we went to the monastery of Poblet, full of mediaeval grandeur between its ancient walls and echoing halls. Another year we headed towards the sources of the river Llobregat, with a previous stop at La Pobla de Lillet, where we took a small train, a former service train for the local extractive industry, now converted into a touristic attraction, to the Gardens of Artigas, designed by Gaudí. After strolling for a while through the enchanted scenery, we continued with the bus to the sources and afterwards still to the small village of Castellar de n'Hug, with its spectacular views and its giant croissants. The last year under Federico's direction our destination was CosmoCaixa, the museum of sciences in Barcelona, which was unknown by many




Top: Wine tasting in Albet i Noya, Christmas 2007. In this photo you may find three of IRI's directors. On the right, Federico Thomas, Carme Torras, and Alejandro Agostini, happily holding a souvenir from the visit.
Bottom: Tom Creemers and Pablo Jiménez performing their famous magic trick with cava corks. And, on the right, the *calçotada* at the restaurant.

of our foreign students, and some locals also. Equally memorable was the lunch afterwards, in a nearby restaurant specialized in roasted or grilled meat in all of its variants, also grilled vegetables were offered to the vegetarian colleagues, accompanied by strong red wines. We didn't know that it was going to set a precedent some years later, on a quite local basis.

The Christmas lunch tradition was still maintained in 2008, with an excursion to the monastery of Sant Benet de Bages, nearby Manresa, which included a visit with projections about the monks lives, as well as a visit to the adjacent villa of the Casas, the family of the well-known Catalan modernist painter Ramon Casas i

Roasted and grilled meat was to become our future Christmas lunch basis, although not in such a fashionable restaurant. In the bottom right frame, in winter 2008, scientific hearts were not immune to the charms of a well-told story about mediaeval monks in Món Sant Benet.

Carbó, and to the *Fundació Alicia*, devoted to technological innovation in cuisine, the improvement of eating habits and the evaluation of the food heritage (in their own words), where many of us learned the meaning of the word umami for designating the fifth basic taste.

Group photo at Fundació Alícia.

This was to change in the forthcoming years. The worldwide economic crisis meant not only lowering the budget for research and new contracts, but had also consequences on our social activities, and not necessarily for the worst, as described in the next section.

It also was about those years when a long-lasting activity began, namely football playing. The proximity of the FC Barcelona stadium *Nou Camp* possibly inspired students and young researchers to engage in a regular meeting at the University sports fields to run after the ball and to kick it. While at the beginning the

IRI football team, 2017-2018, proud of defending their colors.

matches involved just the IRI's amateurs, some years later they participated in Faculty and UPC-level tournaments. Even a special uniform was designed to this end.

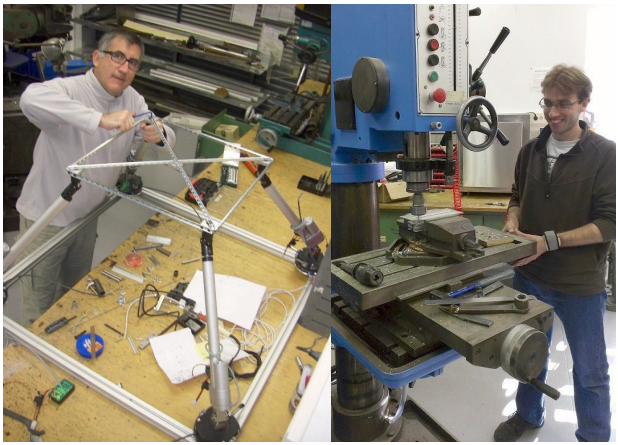
CHAPTER 4 - 2010 - 2016

NEW LABORATORIES, NEW INCORPORATIONS, AND SOME DEPARTURES

Premises, equipment and research

2010 was again an important year as for spaces and laboratories. Additional 232 m^2 where gained at floor level 0. This was in some sense the execution of the agreement of 2004, gaining two additional spaces between columns. The conditioning works included the construction of a concrete floor between floor levels 0 and 1. Before that, this was an open space reaching the ceiling of floor 1. CDEI, previously occupying the space at level 0, received new space gained at the same floor level 1 where they already had other offices. IRI gained offices as well

as laboratory space. The works were carried out in summer 2009 so as to cause no disturbance during the academic course, and the final finishing works, including a new access door, extended until spring 2010. These new spaces hosted the Mobile Robotics Lab and the new Kinematics and Robot Design Lab. Next to the laboratory of Mobile Robotics, the new Workshop began to be equipped with the necessary machines, tools and instrumentation to provide their services in mechanics and electronics.

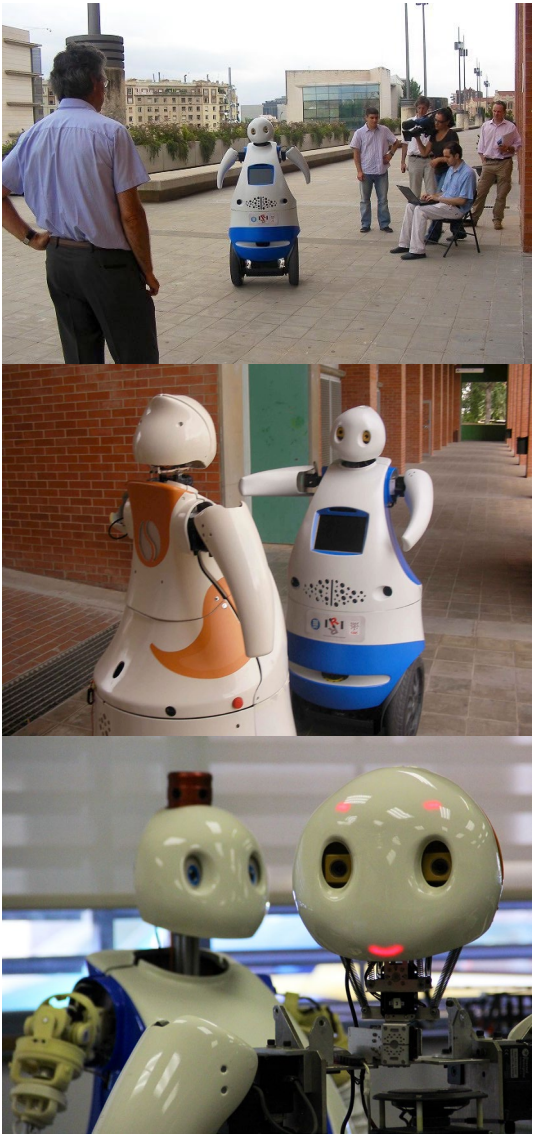


Patrick Grosch and Sergi Hernandez in the workshop.

Meanwhile, the Mobile Robotics group was enriched by new members, and not only human ones: in the context of the already mentioned EU Project URUS, two user-friendly urban service robots on Segway platforms were built, Tibi and Dabo. Their kind appearance aimed at encouraging humans to engage interaction with them, e.g. by seeking information in an urban environment.

They were not only tested in the aforementioned Barcelona Robot Lab, but the final demonstration of the project URUS included also their deployment in the Passeig de Sant Joan, in the popular quarter of Gràcia in Barcelona. These robots displayed the

expansion of the research interests of the group from mere navigation and map building to human-aware navigation and social interaction. In fact, two main topics developed along (or across) their six current research areas, namely last-mile urban robotics and human-robot interaction, with projects and theses led by Alberto Sanfeliu, and mobile robotics without human interaction, including AGVs and autonomous driving, UAVs, etc., research led by Juan Andrade. The fleet of mobile ground robots increased these years with the autonomous vehicle IRICar, distributed by Robotnik, and the mobile platforms for educational purposes IRIkobukis by 2012 (aka TurtleBots), from Yujin Robots. These new trends reflected in the EU projects that began during this period. CEEDS: The collective experience of



Top: Dabo facing his creator, Alberto Sanfeliu, while filmed by a local TV. Middle: Tibi and Dabo, meeting at Barcelona Robot Lab. Bottom: Tibi and Dabo at the Mobile Robotics Lab.

Àngel Santamaria explains his colleagues the challenges involved in piloting an aerial manipulator.

empathic data systems (2010-2015), PI Alberto Sanfeliu, bases on the axiom that discovery is the identification of patterns in complex data sets by the human brain and seeks to exploit such implicit information processing capabilities via augmented reality environments. On the other side, research in the group literally takes off via the project ARCAS: Aerial Robotics Cooperative Assembly System (2011-2015), which had later continuity in AEROARMS: Aerial robotics system integrating multiple ARMS and advanced manipulation capabilities for inspection and maintenance (2015-2019), both led also by Alberto Sanfeliu, consolidating the research focus towards the anew topic of robotic aerial manipulation. UAVs employed in these projects were Kinton, a Pelican Quadrotor from Asctec, and Ona, built by

Ascamm (later Eurocat), which had to be equipped with a surrounding frame to render it intrinsically safe for HRI, but had to face some constructive difficulties. Later, a commercial DJI Matrice 600 was acquired, on which different devices were mounted for sensing. Àngel Santamaria's PhD thesis spurred from this research, and was nominated to the EURON Georges Giralt Best PhD Award in 2018.

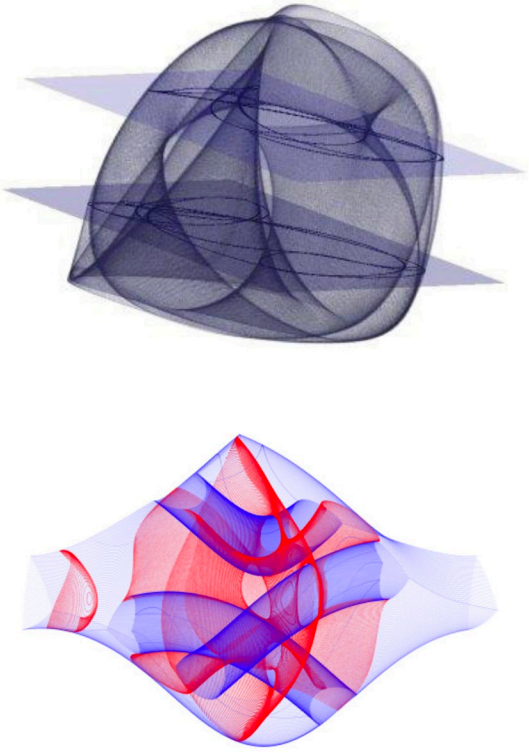
Autonomous Volvo truck and straddle carrier of the Cargo-ANTS and LOGIMATIC projects. On the right, Juan Andrade and colleagues from the Spanish and Greek technology centers EURECAT and CERTH on top of the port container carrier.

Returning to the ground, both Cargo-ANTS: Cargo handling by automated next generation transportation systems for ports and terminals (2013-2016) and LOGIMATIC: Tight integration of EGNSS and on-board sensors for port vehicle automation (2016-2019) (PI Juan Andrade) focused on autonomous freight transportation and handling in harbor environments with final demonstrations taking place in Stora Holm, Sweden, using automated Volvo trucks for the Cargo-ANTS project, and in Thessaloniki, Greece, for the LOGIMATIC project with a custom built autonomous straddle carrier specifically retrofitted for the project. These have been by far the largest, heavier, and most dangerous robots IRI researchers Andreu Corominas, Joan Vallvé, and Joan Solà have worked with to date, inspiring some of the work taking place years later on robot safety and HRI.

Last but not least, the project ECHORD++: European clearing house for open robotics development plus plus (2013-2019) (PI Alberto Sanfeliu) aimed at consolidating Europe-wide consortia of academia and industry to the actual development of robotic solutions for public needs, such as the pre commercial robotic products for inspection and maintenance of the sewer network to be made available to the cities.

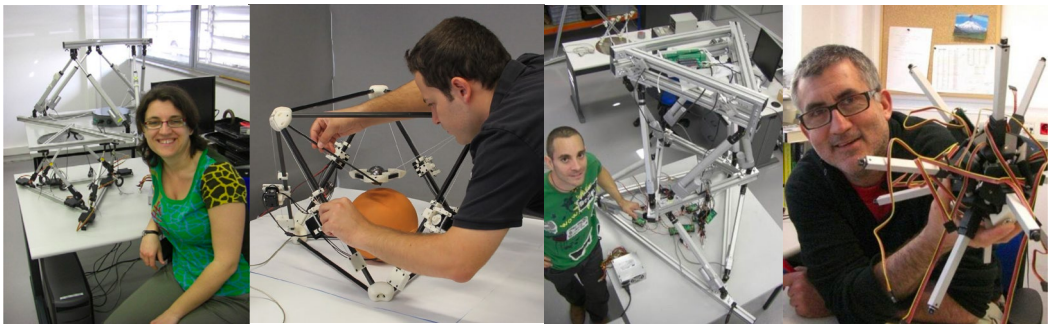
As for the Kinematics and Robot Design group, they had excelled in theoretical contributions in synthesis of linkages, as well as position analysis and singularity characterization of complex multiloop mechanisms. The latter had fructified, via a series of national projects from the 2005-2008 project CUIK: *Planificador de trayectorias para sistemas robotizados de arquitectura arbitraria* to its extensions CUIK+ and CUIK++, spanning from the end of 2005 to 2013, with Lluís Ros as PI, in a homonymous software package, which is available to the scientific community

via a GNU License, for singularity analysis, workspace determination, and dimensional synthesis on multi-body systems of general structure.

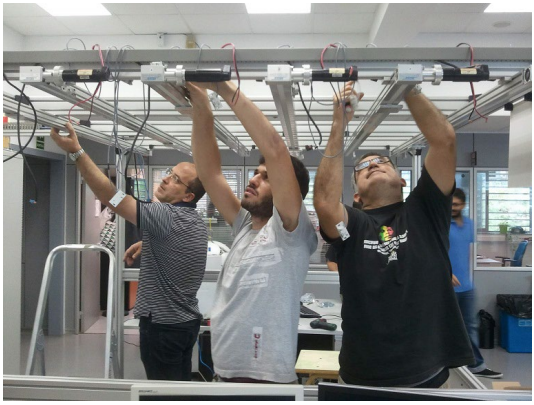


The 3D projections of the multidimensional configuration spaces and singularity loci of various parallel manipulators renders beautiful depictions with intrinsic artistic value.

The new Lab allowed to focus on another research area, namely the design and construction of actual mechanisms. The group had already a long-lasting experience in the always complex construction of real robots, such as a parallel-robot based structure which, by measuring the individual forces on the legs, could determine the position, direction and magnitude of the force exerted on the platform. New developments included an original air-pumped positioning table, several tensegrity-based robots in the context of the National project TenSeBot: *Estudio de estructuras tensegrity para el desarrollo de sensores manipuladores y robots móviles* (2005-2006), led by Josep Maria Mirats), a couple of pentaglides,



Júlia Borràs with octahedral Gough-Stewart platforms, Oriol Bohigas adjusting a cable-driven robot, Josep Camps with a tower of reconfigurable Gough-Stewart platforms, and Patrick Grosch bringing White Herpes to life.



Federico Thomas, Aleix Rull, and Patrick Grosch while constructing the structure of the pentaglide.

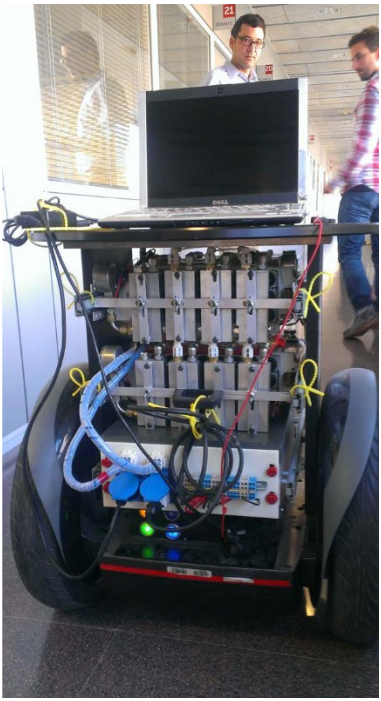
several variations of the Gough-Stewart platform kinematically equivalent to the octahedral manipulator, and a twelve degree-of-freedom amoeba-like robot, called White Herpes. This, in turn, favored the development of projects such *as* RobCab: Control strategies for cable-driven robot for low-gravity simulation (2015-2018), led by Josep Maria Porta. It should be stressed that, almost like living beings, some robots evolved with time undergoing some mutations. For example, one of the pentaglides, a 5PSU with a horizontal base configuration called the ham-holder or *jamonero*, became the vertical Gonorobot. By the way, the driving actuators were the recycled motors of the legged robot ARGOS, and the following mutation introduced one more leg, becoming the hexaglide. If you are wondering about the given names of the robots of this group, there was still an E-bola to come.

Top, the Water-Cycle Control Systems Lab. Below, a brainstorming session at the Fuel Cell Control Lab.

This increment of available space did also allow to create the Water-cycle Control Systems Laboratory at floor level 2, next to the Fuel Cells Lab. The purpose of this facility is to test and validate modeling and advanced control methods for dynamic systems associated to industrial processes as well as to systems for water cycle management. To this end, it includes platforms of pressure, flow and level processes for water and for energy and power efficiency emulators of industrial processes, over which it is possible to implement real-time advanced control strategies.

This expansion in available space was also coincident with a blast-off of the Automatic Control group as for European projects. For example, in the domain of fuel-cell control, there

were ACOFC: Advanced Controllers and Observers Development for Fuel Cell based Generation Systems (2011-2013) led by Christian Kunusch, ACRES: Advanced control of renewable energy generation systems based on fuel cells/wind power (2012-2013) and PUMA MIND: Physical bottom Up multi-scale Modelling for Automotive PEMFC Innovative performance and Durability optimization (2012-2015), both led by Jordi Riera.



Fuel-cell enabled mobile robot, developed by the automatic control group for the mobile robotics group.

Regarding the control and management of complex systems such as water or energy distribution networks, the projects EFFINET: EFFicient Integrated real-time monitoring and control of drinking water NETworks (2012-2015) and EFFIDRAIN: Efficient integrated real-time control in urban drainage and wastewater treatment plants for environmental protection (2015-2019), both led by Gabriela Cembrano, as well as GRACeFUL: Global systems rapid assessment tools through constraint functional languages (2015-2018) (PI Tom Creemers) and INCITE: Innovative controls for renewable sources integration into smart energy systems (2015-2019) (PI Carlos Ocampo, who had been at IRI since the end of 2008) can be included in this period. The latter has to be stressed as it was not a typical research nor technology transfer project, but a Marie Skłodowska-Curie Action on Innovative Training Networks, a Europe-wide training

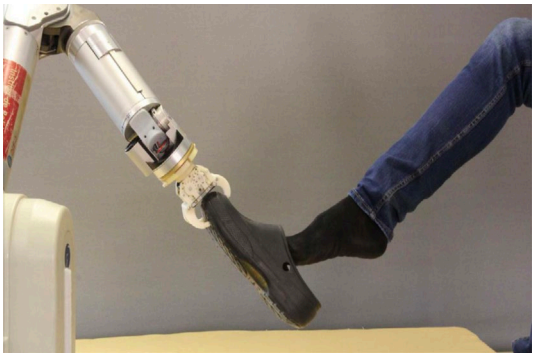
network for researchers in the beginnings of their research careers, PhD students mainly.

For the GARNICS project, a WAM robot arm holds a time-of-flight camera and two tools for chlorophyll measurement and leaf sample cutting.

The potential and real applications of robotics go far beyond industrial premises, and the manipulation of soft objects widens this scope dramatically. The GARNICS: Gardening with a cognitive system EU project, with Carme Torras as PI at IRI, starting in March 2010, involved plant sensing and manipulation, being one of the noteworthy outputs, as from the hardware side, a robot-based leaf probing system.

But the most challenging material to be manipulated, with a huge application potential, is cloth. In the years to come, and still nowadays and in the future, the robotic manipulation of fabrics, mainly in the form of garments but also as other objects in the household (sheets, tablecloth, napkins, etc.) would become one of the main research topics of the Perception and Manipulation group. The EU project I-Dress: Assistive interactive robotic system for support in dressing, starting towards the end of 2015, was the first important step in this direction. Also with Carme Torras as its PI, this project focused on proactive robotic assistance in dressing to disabled users or users such as high-risk health-care workers, whose physical contact with the garments

must be limited to avoid contamination. During this project we counted with the collaboration of the Serbian postdoc Aleksandar Jevtić. This project allowed to gather the necessary background for the ERC Grant project CLOTHILDE, which will be addressed (unintentional pun) below.



WAM robots were also used for human dressing experiments in the I-Dress project. No subjects were harmed during these experiments,

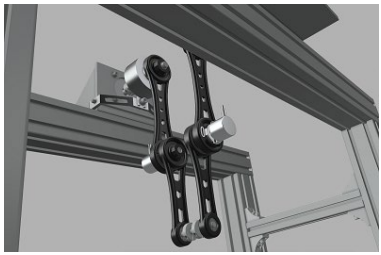
Also exploring new trends in Robotics, but now on the topic of the semantic content of perceptions and actions, the projects IntellAct: Intelligent observation and execution of Actions and manipulations (2011-2015) (PI at IRI Carme Torras) and ViSen: Visual Sense, Tagging visual data with semantic descriptions (2013-2016) (Francesc Moreno as PI) meant also important contributions to the field. During IntellAct and also in GARNICS we had the collaboration at IRI of Babette Dellen, with her know-how in image processing and understanding.

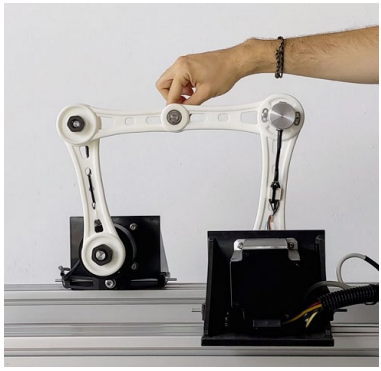
As for PhD theses of today's members of IRI defended during this period, we have to mention our current deputy director Júlia Borràs Sol (2011), one of the driving forces of the Fuel Cell Lab

of the Automatic Control group Attila Peter Husar (2012), the very active member of the Mobile Robotics group Anaís Garrell Zulueta (2013), the nowadays representative of doctors at the Board and since many years responsible of the workshop, Patrick John Grosch Obregón (2016), and the responsible of the new Perception and Manipulation laboratory Sergi Foix Salmerón (2016).

The excellence of our students (and of their directors) was rewarded during this period by having Oriol Bohigas, Anaís Garrell, and Carlos Rosales holding the first, second, and third place respectively for the 2013 Best Robotics PhD of GTRob CEA-IFAC. A few years later Gonzalo Ferrer Mínguez was also finalist for the George Giralt PhD Award 2016.

In 2016 Beta robots was founded. This robotics services company, which bridges the gap between state of the art research and working innovative robotics systems, is not exactly a spin-off, but it was created by three former IRI PhD students, now doctors, namely Andreu Corominas, Carlos Rosales and Oriol Bohigas, with the later addition of Ricard Bordalba. A quite recent fruit of their





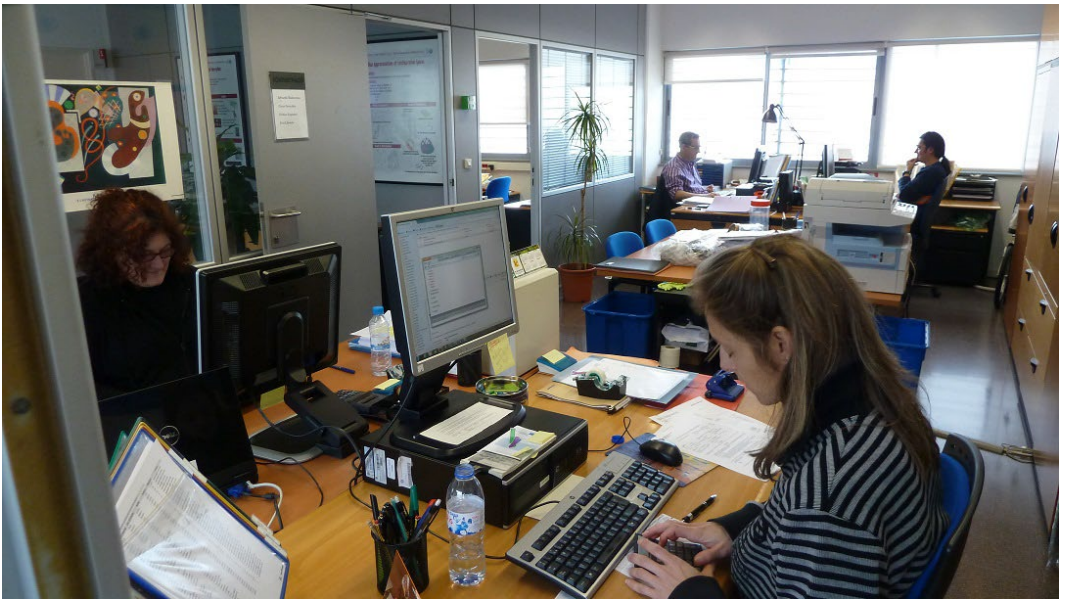
Robots built at Beta robots. In the middle, a CAD model of Sherbot. Below, the user tests the shakiness at the singular configuration.

collaboration with IRI is the robot Sherbot, a planar 2 RRR robot which is able to traverse singularities in a controlled fashion.

Organization and personnel

In 2010 Víctor Vílchez joined the general support staff, revealing himself along the years as one of the most competent members of our Institute, as for its general functioning, and specially in his field, namely tech transfer and dissemination. As for the latter, it is well-known that social network services are gaining relevance for reaching the public and constitute a good way of publicizing research activities, concurrently to traditional mass media. For this reason, starting in 2011 IRI became present in social media by creating Facebook and a Twitter accounts, as well as a YouTube channel. More on the professional side, also a LinkedIn account was initiated, with special significance for our job offers.

This very same year, Alberto Sanfeliu cofounded SEIDROB, the Spanish association for the investigation and development of robotics. Also that year, Eva Llavería joined the administrative staff, and she would remain until May 2019.



The administrative staff in 2013, tirelessly putting the grease in the machinery to allow a smooth running of the institute. From left to right, Eva Llavería, César González, Esther Expósito, and Eduardo Ballesteros.

Joaquim Blesa joined the Automatic Control group in 2013, contributing on topics of monitoring and control, mainly of water distribution systems and with emphasis on leak localization. The same topics are also within the expertise of Sebastian Tornil, who, although officially ascribed to IRI in 2015, had collaborated with the group already in 2011. In 2013, Ana Maria Puig-Pey joined IRI, as faculty researcher in projects of the Mobile Robotics group.

In 2014 Juan Andrade was elected director of IRI. During the first years (until April 2018), Carlos Ocampo was his deputy director. As a director, one of the main concerns of Juan Andrade was to foster the scientific production of the institute.

In November 2015 Antonio Agudo joined IRI, although he had been already collaborating with Francesc Moreno time ago,

providing his expertise in physical modeling, as well as learning and optimization, with applications to computer vision. Their research was reinforced the following year with Albert Pumarola starting his PhD thesis “Bridging the gap between geometry and deep learning”, codirected by Francesc Moreno and Alberto Sanfeliu. Also in 2016, in June, Carmen Fernández joined IRI, in the administration, and Ana Isabel Morales joined the Transference and Dissemination Office, ruled by Víctor Vílchez, where she is a valuable help, mainly in what concerns her specialty, image and audiovisuals.

2016 was also the year marked by two farewells. The year started with the leaving of Ana Canales, who had gained a position in the administration of the School of Architecture, and some years later would be the Head of the International Projects Unit of UPC. She really deserved the best for her career, but it was of course a heavy blow for the administration of our institute. Only the engagement and commitment of the administrative team allowed to keep forward for some years without a general manager. The second equally marking departure was the retirement of Jordi Riera. On November 25th a tribute act was paid to him, which included not only institutional speeches, but a kind of biographic video in humorous terms, as well as congratulation videos gathered from all over the world from his former colleagues and students. He left not only a reference lab and team in fuel cells, but also sweet memories in his colleagues of his kindness and politeness.

Although Ramon Costa had been collaborating earlier with Jordi Riera and Maria Serra, his commitment with the Fuel Cells Lab was formalized by his ascription to IRI in the beginning of 2017.

Social life

As for the social part of those years, we had two annual gatherings. The summer lunch in an affordable restaurant by the seaside was the closing act of the "doctoral day," where PhD students explained to a scientific committee formed by senior researchers what had been their progress during the last year and received some orientation. The Christmas lunch, on the other hand, was completely reinvented: it became a cuisine contest, where the members of the IRI family contributed with their exploits in different modalities: entries and snacks, main dishes and desserts. In the first modality, the extraordinary delicatessen

The first on-site Christmas celebration was quite exhausting with some sports played.

provided by Ana Canales, when she was about to leave the institute, are unforgettable for those of us who had the privilege of tasting them. Also the cakes made by Ely Repiso stood out for

their artistic conception. Some years later and until the pandemic, a modified format was devised, namely having grilled meat as main dish, thanks to a yearly increasing number of grills, and the expertise of Attila Husar (he has an Argentinian fiancée), Patrick Grosch and Juan Andrade, among other volunteers. The barbecue experience had already had a precedent in the successful

The Catalan holiday tradition of *Fer cagar el tió* was honored. It consists on feeding a log with scraps of food some days before Christmas. Then, it's beaten with a stick and implored with a song to poop out hazelnuts and a nougat called *turrón*.

The *calçotada* experience in 2017 set the precedent for the barbecue events to come. In selfie mode, Aleksander Jevtic, Fernando Herrero, Joan Vallvé, and Àngel Santamaria.

calçotada organized by Gerard Canal at the beginnings of 2017 in a small village nearby Barcelona.

The space at the laboratories at floor level 0 and the outside next to the workshop came in handy to gather all the people, distribute the grills, the buckets with ice and drinks, and the tables with the dishes, as well as being the playground for the different activities that took place. As for the latter, the most remarkable was doubtless the Agustins IRI Awards Ceremony, which in its first two editions (2015 and 2016) was held in the summer lunch, later (2017-19) always during the Christmas lunch. These humorous awards, which rewarded categories such as the longest or the best paper title, the farthest country of origin, or the hardest working conditions, among many others, were an initiative of the "tupper team", the students who met daily to lunch with their tuppers): Àngel Santamaria, Gonzalo Ferrer, Toni Gabàs, Sergi

Foix, Fernando Herrero, Joan Vallvé and Martí Morta. In later editions important contributions were also made by Antonio Rubio who did all the videos, Ely Repiso, Victor Sanz, Alejandro López, Ricard Bordalba, and many others, not to forget the help of Victor Vílchez or of Patrick Grosch with his 3D printing skills. The prize consisted in a 3D print statuette reproducing at a small scale the child mannequin we had at the Robotic Cell laboratory, which had been originally acquired for learning from demonstration in dressing experiments. Why the mannequin itself bears that name is confidential, only a small group of initiated know the reason, this chronicle does not pretend to air all of IRI's secrets.

The Agustin award figurines (the influence of the Oscar statuette is hard to overlook) and one example of nominees, in this case to the hardest working conditions.

Our colleagues may have unknown talents and hobbies; it is a kind of precious pearl when they decide to share their wisdom or abilities. This was the case of Attila Husar and the IRI Beer Brewing Workshop (IRIBirra) he organized in different sessions along April-May (*Hefeweizen*, following the Bavarian *Reinheitsgebot*) and June-July 2016 (IPA, this time together with the visiting researcher Jan Funke). The workshop included both

Jordi Riera, Attila Husar, and Ana Canales. They are not rehearsing the witches scene in Shakespeare's Macbeth, but stirring the substance of what will become tasty *Hefeweizen* beer.

the brewing, with different batches altering the brewing conditions, as well as the tasting of the end products after

fermentation. The experimental variables were tightly controlled, and tasting was thoroughly conducted with increasing joy, so in fact the whole activity could be viewed as biochemistry research.

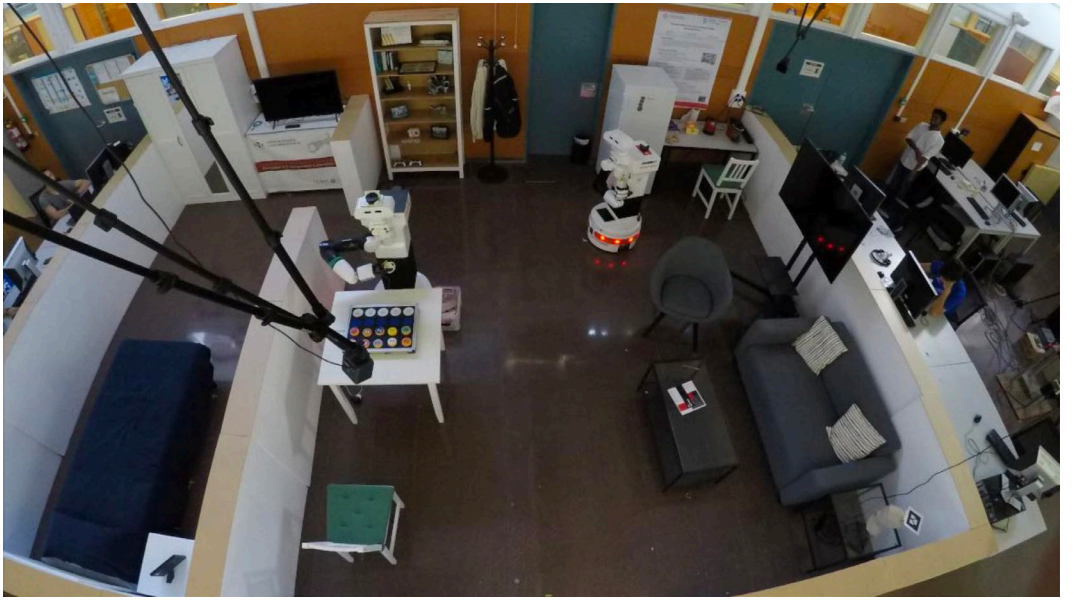
CHAPTER 5 - 2017-2021

THE EXPANSION AND HOW TO HANDLE AN INTERNATIONAL HEALTH CRISIS

Premises and equipment

The constant growing of IRI, from about 70 people in 2007 to 178 at present, has motivated the need of more space, and in response to this demand recent agreements with the ESAII department, the FME and the ETSEIB, have granted the expansion towards the 2nd floor east wing of FME, which now hosts offices and the Perception and Manipulation Lab, as well as in the ETSEIB across the street, now hosting offices and laboratories of the Kinematics and Robot Design group. The conversations for the first of these spaces, the east wing of FME, started already in 2017, the works to arrange the laboratory were performed during the summer 2018, in September the moving began, and in October 15th an IKEA furniture mounting action was carried out, to equip the "intelligent apartment" inside the

laboratory where the assistive TIAGo robots were going to dwell and be trained to do their daily household chores. Once more, the human IRI members had a chance to demonstrate their versatility, their spatial geometric reasoning prowess, and their manual dexterity. The mock-up apartment occupies 35 m^2 of the 152 m^2 of the Perception and Manipulation laboratory, and it surely does also serve as a casual space for students working until late, as it has a sofa and a bed. Some elements of the apartment are controlled domotically via ROS. For instance, the position of the curtains can be controlled and door state, temperature or human presence in a room can be sensed. For this reason, in the mood of semantic generosity, it is also called the intelligent apartment, but



How many apartments do you know with two robots at your service?

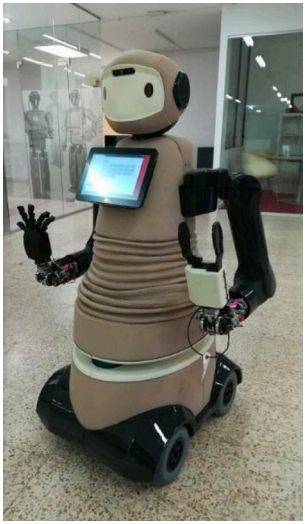
more often it is just called “the apartment”, in an unconscious homage to Billy Wilder’s movie.

The laboratory counts also with a manipulation area with two Barrett WAM arms and one KINOVA Gen3 robot. Workplaces are distributed around the perimeter, allowing a considerable number of students to work next to the experimental platforms.

As for the IRI spaces gained in the ETSEIB building which now host the facilities and offices of the Kinematics and Robot Design group, they are the result of conversations carried out with the directive team of ETSEIB during the first half of 2019, and formalized via signature of an agreement in June that year. The

The Kinematics and Robot Design Lab at the ETSEIB building. At the right, the Franka Emika Panda arm, and at the centre E-bola and E-boludo.

Engineering School provided the spaces while IRI had to assume the reformation costs. These were not minor, as the spaces are located in a rather unpopulated wing of the building, untouched for some decades. The real facts about the ETSEIB building, in its more than 50 years of history, are almost as incredible as the myths that have been circulating among generations of students. After chasing the tumbleweeds rolling along the corridors and removing some unidentifiable remains found below tons of manuscripts on steam engines, the renovation works, separating walls, new floor and doors, air conditioning etc., began between the second half of 2019 and the beginnings of 2020, but had to be interrupted due to the pandemic. The same happened with the offices to be reformed at the second floor in the FME next to the Perception and Manipulation laboratory. All these works couldn't be resumed until the second half of 2020, and the spaces couldn't



IVO was presented at the Smart City Expo World Congress on November 2019. It is now a member of an ever growing family.

be inhabited until the beginnings of 2021. As for today, in IRI's spaces in the ETSEIB and besides the offices, there is a 75 m^2 laboratory, which contains the prototypes developed and constructed by the group, including the most recent planar 5 RRR with a pentagonal reconfigurable end-effector, or the parallel spherical 3-RRR manipulator. It hosts also the Omnibot, an omnidirectional mobile platform, as well as the serial manipulators of the group: the old-timer Stäubli robot arms, the even more ancient Zebra Zero, and a manipulation cell with the Franka Emika Panda (2018) and the Universal UR3 (2020) compliant robots.

The Mobile Robotics group took one step forward in their commitment to social robotics with the acquisition, in 2019, of the robot IVO. Building on existing standard robotic equipment, IRI commissioned the *Escola Superior de Disseny* and PAL Robotics the characterization of a collaborative robot, which included the design of its appearance, the use of novel, soft materials, and its naming.

Research and education

2017 was the year of two quite significant achievements, which boosted the institute's relevance, both at national and international level. On the one hand, the success of the collective endeavor of the research done at IRI was awarded with the María de Maeztu scientific excellence seal by the Spanish State Research Agency for the period 7/2017-6/2021. The strategic research program focused on human-centered robotics by addressing the following scientific objectives: empathic natural human-robot interaction and collaboration; robust localization

and mapping; dexterous textile manipulation; robot learning using natural communication; energy supply and optimization; supervision and control of complex dynamic systems; and ethical, regulatory and philosophical aspects of social robotics. This achievement had been particularly possible thanks to the initiative of the director Juan Andrade, and the engagement and no surrender of the team involved in writing the proposal. On the other hand, the ERC Advanced Grant Cloth Manipulation Learning from Demonstrations was awarded to Carme Torras and her team, for the period 2018-2023, with the aim of grounding a versatile manipulation of cloth items on both machine learning and computational topology methods. The final objective is to come up with a theory of cloth deformation under manipulation leading to a general framework for robots to learn to manipulate garments from human demonstrations. Such framework will encompass: non-expert teaching of a task, robot perception and skill learning, task-oriented cloth representation, probabilistic

EXCELENCIA MARÍA DE MAEZTU
07/2017-06/2021

AGENCIA ESTATAL DE INVESTIGACIÓN

The María de Maeztu excellence seal.

Carme Torras as holder of the ERC Advanced Grant. By the way, in the photo she is holding Agustín's shoulders.

planning, robot task execution in varying initial conditions, failure diagnosis and informed requests for human help.

Speaking of recognitions, it is time to acknowledge the silent work of generations of young researchers, who, beyond so many hours reading and writing papers, coding, taking and analyzing data, etc., do not recoil from physical engagement, or even to put themselves at risk of suffocation, strangling, extenuation, or beheading.

The subgroup lead by Francesc Moreno has evolved towards an impressive expertise in deep neural network-based reconstruction and animation of non-rigid shapes. The face animation sequences obtained from a single image, by exploiting action units defining facial expressions, are very realistic. You cannot trust photographs anymore!

Other recognitions that happened that year include the CEA Springer 2017 award for the best thesis in Control Engineering in Spain, followed in 2018 by the EECI European Embedded Control Institute award in recognition to the best PhD thesis in Europe in the Field of Control for Complex and Heterogeneous Systems for the PhD student Julián Barreiro Gómez, as well as the Google Faculty Research award 2017 won by Francesc Moreno to develop, in collaboration with Antonio Agudo, Albert Pumarola and Jordi Sánchez and Vincent Lepetit (Université de Bordeaux) geometry-aware convolutional neural networks for non-rigid shape reconstruction.

These weren't of course the only projects obtained during that period. The Mobile Robotics group started in 2017 the EU projects ROBOCOM++: Rethinking robotics for the robot companion of the future (2017-2022) and TERRINET: The European robotics research infrastructure network, an INFRAIA

instrument to provide transnational access to European research infrastructures to researchers, 2017-2021, both led by Alberto Sanfeliu. In 2018, the initiated projects included GAUSS: Galileo-EGNOS as an asset for UTM safety and security (2018-2021) (PI Juan Andrade) and SciRoc: European robotics league plus smart cities robot competitions (2018-2022) (PI Alberto Sanfeliu). And finally, starting this year, the project CANOPIES: A Collaborative paradigm for human workers and multi-robot teams in precision agriculture systems (2021-2024) (PI Alberto Sanfeliu). Noteworthy is the number of projects which aim at creating networks and synergies at international level. The Automatic Control group started INN-BALANCE: Innovative cost improvements for balance of plant components of automotive PEMFC systems (2017-2021), led by Attila Husar, to foster fuel cell technology in the automotive industry. The Kinematics and Robot Design group started two National projects in 2018, MEQUIRP: Mechatronic equipment for a rapid-prototyping lab (2018-2021) (PI Federico Thomas), enhancing the capacity of our institute to develop and test prototypes of different robotic devices and structures, and KINODYN: Kinodynamic planning of efficient and agile robot motions (2018-2021) (PI Lluís Ros) to consolidate their expansion towards the topics of dynamics and control of robots. During this period, specifically in 2017, the E-bola robot was built, a parallel robot which was able to recover the equilibrium of a ball dropped on a platform by following the ball's motion with a camera. As it could not be otherwise, the group recently developed a mutated version of E-bola known as E-boludo. As for the Perception and Manipulation group, they started SOCRATES: Social cognitive robotics in the European society (2016-2020), an MSCA-ITN, PI Guillem Alenyà; IMAGINE: Robots understanding their actions by imagining their effects (2017-2021) (PI Carme Torras),

BURG: Benchmarks for understanding grasping (2019-2022) (PI Guillem Alenyà), IPALM: Interactive perception-action-learning for modeling Objects (2019-2022) (PI Francesc Moreno), and COHERENT: Collaborative hierarchical robotic explanations (2021-2024) (PI Júlia Borràs).

For a second consecutive year a record was beaten as for the number of defended PhD theses. Among the eight presented theses during that year we have to mention Adrià Colomé Figueras who won the Award of the Spanish Automation Committee (GTRob) for the best PhD Thesis in Robotics in Spain in 2017.

At the start of the year 2018 the ERC grant project CLOTHILDE began, and that same year IRI also received the TECNIO accreditation. This seal, awarded by the Catalan government agency for enterprise competitiveness, identifies and provides visibility to technology developers with differential technological capacities and the capability of transferring them in order to strengthen the regional industry. In this line we have to highlight the creation of our first spin-off company, being Guillem Alenyà and Sergi Foix the founding partners from side of the IRI: Datision, aiming to find solutions through the implementation of Artificial Intelligence algorithms in Industry 4.0, as well as to create new opportunities for companies through technology: decision support, optimization of business processes, differentiation through innovation, discovering of new revenue streams, monetization of data with advanced data analysis.

In 2018 and for the next two years, two researchers joined the Perception and Manipulation group, contributing their valuable know-how: Joan Lobo Prat and Javier Segovia.

The parade of awards initiated in previous years continued in 2018: the already mentioned award to Adrià Colomé; the paper Dynamical tuning for MPC using population games: A water supply network application, by Julián Barreiro, Carlos Ocampo-Martínez and Nicanor Quijano received the ISA Transactions Best Paper Award in 2018. Further recognitions included IRI's merits during the 2017/2018 academic year by the mother institution CSIC, the nomination of Carme Torras as IEEE Fellow, and the nomination at the European Robotics Forum of Àngel Santamaria and Adrià Colomé as finalists to the Georges Giralt PhD Award. Within the same forum, the IRI@ERL team was winner of two European Robotics League (ERL) competitions.

Tecnio accreditation seal and logo of IRI's first spin-off, Datision.

A fine initiative to be stressed, because it was born from a selfless desire to share knowledge that could be useful in different branches of robotics and control, was the course offered and taught by Joan Solà on Lie theory for estimation in robotics. Later, with the same spirit, Lluís Ros shared the class notes he had taken, with all the attendants to the course. Beyond the regular seminars of IRI members and visiting professors, organized during many years by Josep Maria Porta (we cannot thank him enough for the effort and push he has put into it for so long), this course given along three sessions (November the 8th, 15th and 22nd 2018) had the virtue of making us feel like young students again, as stated in the received best social initiative of the Agustín Awards that year.

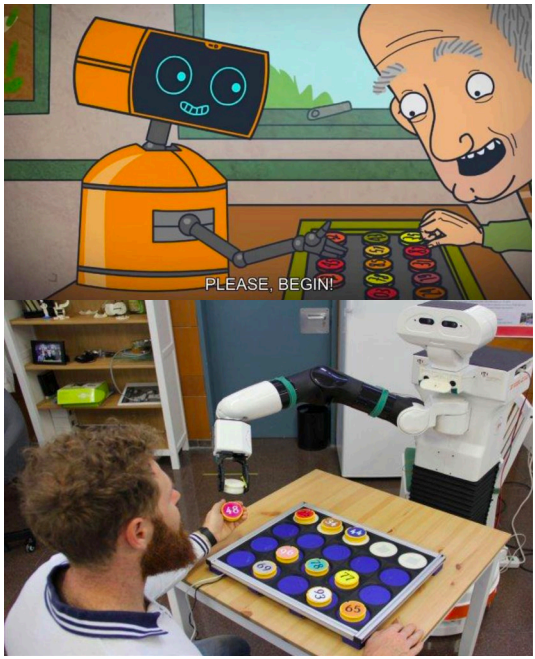
Sometimes our research is applicable in other fields than those strictly related to robotics or the control of networks, energy generation and industrial processes. The Kinematics and Robot Design group has demonstrated this repeatedly by showing how their methods can be applied to proteomics (the biochemical study of proteins) and to molecular conformation in general. The use of convolutional networks for the automatic diagnosis of muscular dystrophies related to collagen VI, conducted among others by Josep Maria Porta, has later led to a technology transfer contract, COL-VI: Automatic diagnosis of collagen VI-related muscular dystrophies (2020-2022), whose PI is also the head of the Kinematics group.

Colleagues as students. Joan Solà initiating us in the arcane mysteries of Lie Theory.

New prizes and recognitions were awarded to IRI members during 2019: Carme Torras is recognized as the Catalan ICT professional of the year and receives also the IV Julio Peláez Award. Recently presented doctoral received also recognition: Ye Wang won the Award of the Spanish Automation Committee for the best PhD Thesis in Control Engineering, Edmundo Guerra the UPC *Premi Extraordinari de Doctorat Award* in the 2016/2017 promotion, delivered in 2019; and Javier Segovia the Award of the European

Association for Artificial Intelligence for the best PhD Thesis in Artificial Intelligence in 2018.

On the dissemination side, Antonio Andriella, a Marie Curie PhD student, won the MSCA video contest organized by the Marie Curie Alumni Association, with the collaboration of VIKKI Academy, an audiovisual company: an animated video on assistive robotics in the rehabilitation of Alzheimer's disease, in the context of the SOCRATES project, *I Robot, U Patient*, was produced.



A frame of the short I Robot, U Patient. Below, Antonio Andriella tests TIAGo's patience.

The stream of recognitions and awards goes on in 2020. Starting again with Carme Torras, she received the National Research Award Julio Rey Pastor. Moreover, she joins several important advisory committees, including the Artificial Intelligence Advisory Council constituted by the Spanish Government, CSIC's Ethics Committee, and also the recently created UPC's Ethics Committee. The Marc Esteva Vivanco prize to the best PhD Thesis in AI goes that year to Gerard Canal. Alejandro Suárez, a PhD student of Guillem Alenyà and Carme Torras, wins

the IV Call for Research contracts *Ford Apadrina la Ciencia*, and he is also finalist of the contest *We are Scientists, Get us out of here!*

At institutional level, IRI renews its TECNIO accreditation and enters also the CSIC PTI (Interdisciplinary Thematic Platform) Mobility 2030, whose goal is to address the global challenge of sustainable and healthy urban mobility, finding solutions to reduce emissions and improve the quality of air and life in the cities of the next decade.

Personnel

On the administrative side, during 2017, Maria Isabel Míguez joined the institute as general manager, a position which had not been covered since the departure of Ana Canales, and whose functionalities had to be taken by the administrative staff, mainly by César González. However, for personal reasons she had to leave in summer 2018. One of her major concerns during her work at IRI was to foster administrative procedures electronically, in an attempt to reduce the consumption of physical paper, in an environment-friendly fashion. Also that year, Neus Salleras was appointed as our permanent link to the Faculty's administration, thus participating in the Board's monthly reunions.

Towards the end of 2018, Evili del Rio leaves to CMIMA in service commission, which will affect negatively the maintenance and necessary update of our intranet. On the positive side, Victoria Osuna enters as new manager on July 2019. She has rather a teacher background, but an extraordinary willingness,

dedication and desire to learn, together with the mentoring efforts and involvement of all the administrative team, specially of César González, Víctor Vílchez and Eduardo Ballesteros, allows her to assume most of her duties in a short time. However, in the start of 2020 she goes on maternity leave, assuming Eduardo Ballesteros temporarily her functions. On the scientific side, in February 2019, Mariella Dimiccoli joined the Perception and Manipulation group as Ramón y Cajal postdoc. In September 2020, Cecilio Angulo and Xavier Giró were ascribed to IRI, within the Perception and Manipulation group, providing their valuable background in AI, and in image processing and deep learning, respectively.

The pandemic

This particular history of a research institute in Barcelona has been occasionally driven by world-reaching events. One such event was the already mentioned global financial and economic crisis. But the most direct impact, as for lifestyle and working conditions, has been caused by the COVID-19 pandemic, which at the moment of writing these lines and despite massive vaccination is still quite active. As for March 2020 we had to learn, from one day to the next, the real meaning of the term confinement. We had to stay at home, work from home, learn to have online or virtual or remote meetings, even to attend the online or virtual or remote versions of those conferences which had not been suspended. Sometimes having young children at home, sharing computer and the internet with the online classes of their schools, adjusting our schedules to the necessities of the families. Sadly, we had also to learn the direct consequences of the SARS virus by some of the members of IRI getting ill or even

having to endure the passing of close relatives. The members of the Board had to devise, according to the directives of the Government and of the UPC, all the preventive measures to be observed by those IRI members that sooner or later had to return to use some equipment for experimentation. Their first meeting after the beginnings of the confinement, in April, took place online, a format that would become normal in the months to come, and it was exclusively devoted to this issue. It had to determine room occupancy and ventilation, coordinate the purchase of protective equipment (masks, gloves hydroalcoholic solutions) in a moment where they were scarce and ensure their correct distribution, manage the permits for on-site working, and later the phase-wise plan for de-escalation. The commitment of the director, the Board, and the support personnel as for this crisis has to be gratefully acknowledged, including also the external security and janitor personnel.

In this context, new elections to director and Board were called in fall 2020. The fifth and last elected director, as for these first 25 years of existence of IRI, was Guillem Alenyà. Júlia Borràs, as the deputy director, completes the directing team. One of the first tasks addressed by the new Board was the creation of the Gender Equality Committee, whose head is Júlia Borràs.

Despite the circumstances, the record of three years ago was matched again: eight PhD presentations, the first still presence-based, after the outburst of the pandemics of course via on-line meetings.

Slowly, the worst of the crises passed and, while maintaining all the hygienic measures, people started to return to their physical workplace at the Institute, and experiments were resumed. However, in this new normality, lower shared space occupancy is still encouraged and thus also working from home, at which our proficiency is now much better (the returning of the kids to school may have also contributed to this). We also had new incorporations, such as Maria del Mar Serre in administration, in September.

Experiments were resumed, respecting the mandatory sanitary measures.

In this context, it was no wonder that the actual anniversary of IRI, in November 2020, was ignored, in the hope to pay a better tribute in the year to come.

The new normality

This year 2021 started with the good news of Carme Torras receiving, *ex aequo* with the medical doctor and infectious diseases expert Bonaventura Clotet, the Catalan *Premi Nacional de Recerca* 2020. Also quite positive was the culmination of the reformation works at the ETSEIB spaces, which meant that the Kinematics and Robot Design group could finally move and occupy their new offices and laboratory. Also the works done in

the offices of the second floor of FME at the east wing have allowed them to be gradually occupied.

In the first meeting of the Board this year, a decision was taken to create a commission for the celebration of IRI's 25th anniversary. This commission, whose president is the representative of the PhD students Alberto Olivares, has the duties of organizing different commemorative events, including a contest to change IRI's logo, an art exhibition on robotics and control-related themes, a time-capsule with predictions for the next 25 years, a document on the evolution of robotics and control during the last 25 years, both internationally and at IRIs level, and last but not least, this very same memories book. Also a celebration act, with the presence of some authorities, is planned, subject to the evolution of constraints due to the pandemic.

Unfortunately, Victoria Osuna, who had been back from her maternity leave months ago, had to resign due to personal reasons, but she cared to find a substitute in the person of Diana Herrero, who joined IRI as the new administrative officer in July.

This year, quite recently, has also seen the ascription of Àngel Santamaria and of Alba Pérez, who had collaborated earlier with IRI, in the Mobile Robotics and the Kinematics and Robot design groups, respectively.

Some final remarks

Twenty-five years have passed since the foundation of IRI, twenty since we moved to the FME building. A brief description of our surroundings was made above, at the start of this period, and we have witnessed some changes in these years. The already mentioned disappearance of the cafeteria and the construction of the huge university residence. Across the street, we have also seen how the small nuclear reactor of the ETSEIB was dismantled with great difficulty, as it was a quite robust construction, and the new Nanotechnology building was erected there instead. We have watched the remodeling of the UB buildings on the south side, the faculties of Geography and History migrating to the centre of town and the new buildings becoming part of the Scientific Park of Barcelona. On the west side, a broad pedestrian area with rows of *Tipuana Tipu*, whose yellow flowers cover the ground in June like a beautiful carpet, we have beheld the layout works of the tram rails and one station. Also some works widening the sidewalks and reordering the parking space have been done on the east side, always with a loss of available parking space.

IRI has grown a lot during these years, both in personnel and in space. This is possibly due in part to the own vitality of robotics and automatic control. But the foremost ground is without doubt due to the push and the involvement of its personnel, at all levels. How will this continue? Well, most of us pioneers, those who were there at the very beginnings in the Nexus building, are facing retirement in a decade or less. However generational renewal is guaranteed, in fact our two last directors obtained their PhD within the same Institute. Maybe there will still be some

growth, and maybe, due to the requirements of an increasingly technological society, this expansion will be bigger than we can figure out now. Nonetheless, as important as growth is consolidation. This goes through maintaining the high quality levels that have characterized the research at the Institute so far. Testimony of this is the existence at IRI of four consolidated research groups recognized by the Catalan administration: VIS: *Grup consolidat de Visió Artificial i Sistemes Intel·ligents*; RobIRI: *Grup consolidat de Percepció i Manipulació Robotitzada de l'IRI*; KRD - *Grup consolidate de Cinemàtica i Disseny de Robots*; and SAC: *Grup consolidate de Sistemes Avançats* de Control. Our International projection is also quite solid, with a considerable number of EU projects ongoing, as well as foreign PhD students.

The research topics covered by IRI researchers have an obvious impact on society, and will rise even further in the years to come, as robotics technologies permeate into the society. While pursuing our research with no other constraints than scientific consistency, it is also true that we cannot ignore the potential ethical concerns that come by the hand of more and more sophisticated and autonomous robots, and more and more advanced control systems of energy generation, distribution networks, and industrial processes. We have already started to address such issues, with dissemination talks and publications, the initiative *Joves, Ciència i Ètica* organized by the *Fundació Catalana per a la Recerca i la Innovació* and *l'Obra Social la Caixa*, whose 2017-18 edition was devoted to roboethics, the cycle of panel discussions Dialogues on robotics and ethics at CosmoCaixa in the context of the exhibit *Robots. Humans and machines,* and the direction of Júlia Pareto's PhD thesis, *Robótica e inteligencia artificial: (re)flexiones éticas para el*

apoderamiento humano en una era disruptiva by Carme Torras and the philosopher Begoña Román. This involvement and requirement of interdisciplinary work will surely increase over the next years.

We will see if this prediction holds in the revised editions of the history of IRI in the years to come.

APPENDIX A

LIST OF IRI PHD THESES

Name, title, and director(s)

* All theses were carried out at UPC, unless otherwise indicated.

1996

Vicente Ruiz de Angulo García, *Interferencia catastrófica en redes neuronales: soluciones y relación con otros problemas del conexionismo*, Carme Torras, Universidad del País Vasco.

1998

Pablo Jiménez Schlegl, Static and dynamic interference detection between non convex polyhedra, Carme Torras.

Albert Castellet Llerena, An interval method for solving inverse kinematics problems, Federico Thomas.

Judit Martínez Bauzà, Accumulation moments. Theory and applications, Federico Thomas.

2000

Lluís Ros Giralt, A kinematic-geometric approach to spatial interpretation of line drawings, Federico Thomas.

Elisa Martínez Marroquín, Recovery of 3D structure and motion from the deformation of an active contour in a sequence of monocular images, Carme Torras, Universitat Ramon Llull.

2002

Ernesto Staffetti, Local characterization of the configuration space, Federico Thomas.

2003

Juan Andrade Cetto, Environment learning for indoor mobile robots, Alberto Sanfeliu.

2005

Eduardo Todt, Visual landmark detection for navigation in outdoor environments, Carme Torras.

Josep Maria Porta Pleite, Behavior-based robots and reinforcement learning: A case study on legged robots, Enric Celaya.

Josep Maria Mirats Tur, Qualitative modeling of complex systems by means of fuzzy inductive reasoning, Rafael Huber.

Jaume Vergés Llahí, Color constancy and image segmentation techniques for applications to mobile robotics, Alberto Sanfeliu.

Francesc Moreno Noguer, Multiple cue integration for robust tracking in dynamic environments: Application to video relighting, Alberto Sanfeliu and Peter Belhumeur.

2007

Teresa Alejandra Vidal Calleja, Visual navigation in unknown environments, Juan Andrade and Alberto Sanfeliu.

Guillem Alenyà Ribas, *Estimació del moviment de robots mitjançant contorns actius*, Carme Torras.

2009

Diego Feroldi, *Control de sistemas basados en pilas de combustible tipo PEM*, Maria Serra and Jordi Riera.

Nicolás Amézquita Gómez, A probabilistic integrated object recognition and tracking framework for video sequences, René Alquézar.

2011

Júlia Borràs Sol, Singularity-invariant leg rearrangements in Stewart platforms, Federico Thomas.

Alejandro Gabriel Agostini, Q-Learning with a degenerate function approximation, Enric Celaya.

Andreu Corominas Murtra, Map-based localization for urban service mobile robots, Josep Maria Mirats and Alberto Sanfeliu.

Salvador de Lira Ramirez, Model-based fault detection and isolation for a PEM fuel cell system, Vicenç Puig.

2012

Gerard Sanroma Güell, Graph matching using position coordinates and local features for image analysis, René Alquézar and Francesc Serratosa.

Attila Peter Husar, Performance indicators for the dynamic modeling and control of PEMFC systems, Maria Serra and Jordi Riera.

Vanesa García Mariel, *Modelado y control de un reactor de producción de hidrógeno para la alimentación de pila de combustible*, Maria Serra and Jordi Llorca.

Nicolás Rojas, Distance-based formulations for the position analysis of kinematic chains, Federico Thomas.

Mauricio Primucci, Experimental characterisation and diagnosis tools for proton exchange membrane fuel cells, Maria Serra and Jordi Riera.

Michael Alejandro Villamizar Vergel, Efficient approaches for object class detection, Juan Andrade and Alberto Sanfeliu.

2013

Carlos Rosales Gallegos, Grasp planning under task-specific contact constraints, Lluís Ros and Raúl Suárez.

Rafael Valencia Carreño, Mapping, planning and exploration with Pose SLAM, Juan Andrade.

Oriol Bohigas Nadal, Numerical computation and avoidance of manipulator singularities, Montserrat Manubens and Lluís Ros.

Leonel Rozo Castañeda, Robot learning from demonstration of force-based manipulation tasks, Pablo Jiménez and Carme Torras.

Anaís Garrell Zulueta, Cooperative social robots: Accompanying, guiding and interacting with people, Alberto Sanfeliu.

2014

Joseph Duran, Hybrid modelling and receding horizon control of combined sewer networks, Gabriela Cembrano and Carlos Ocampo.

Stephan Strahl, Experimental and model-based analysis for performance and durability improvement of PEM fuel cells, Attila Husar and Jordi Riera.

Myrna Violeta Casillas Ponce, Leak detection and isolation in water networks, Vicenç Puig.

Feng Xu, Diagnosis and fault-tolerant control using set-based methods, Carlos Ocampo and Vicenç Puig.

2015

Eduard Trulls Fortuny, Enhancing low-level features with mid-level cues, Francesc Moreno and Alberto Sanfeliu.

Juan Manuel Grosso Pérez, On model predictive control for economic and robust operation of generalised flow-based networks, Carlos Ocampo and Vicenç Puig.

Edgar Simo Serra, Understanding human-centric images: From geometry to fashion, Francesc Moreno and Carme Torras.

Gonzalo Ferrer Mínguez, Social robot navigation in urban dynamic environments, Alberto Sanfeliu.

Congcong Sun, Multi-layer model predictive control of complex water systems, Gabriela Cembrano and Vicenç Puig.

Agustin Alberto Ortega Jiménez, Perception and interpretation of dynamic scenarios using LiDAR data and images, Juan Andrade.

2016

Manuel Igelmo Ganzo, The conductance electrical model applied to the graph isomorphism: The star method, Alberto Sanfeliu.

Ernesto Homar Teniente Aviles, 3D mapping and path planning from range data, Juan Andrade.

Valeria Javalera Rincón, Negotiation in distributed large scale systems: A multi-agent MPC architecture, Vicenç Puig and Bernardo Morcego.

Patrick John Grosch Obregón, Parallel robots with unconventional joints to achieve under-actuation and reconfigurability, Federico Thomas.

Sergi Foix Salmerón, Task-oriented viewpoint planning for free-form objects, Guillem Alenyà and Carme Torras.

Syed Farzad Husain, Perceiving dynamic environments: From surface geometry to semantic representation, Babette Dellen and Carme Torras.

2017

David Martínez Martínez, Learning relational models with human interaction for planning in robotics, Guillem Alenyà and Carme Torras.

Julio Alberto Luna Pacho, Development of control systems and state observers for efficiency and durability improvement in PEM fuel cell based systems, Attila Husar and Maria Serra.

Adrián Peñate Sánchez, 3D pose estimation in complex environments, Juan Andrade and Francesc Moreno

Angel Santamaria Navarro, Vision-based autonomous navigation of unmanned aerial vehicles, Juan Andrade.

Julian Barreiro-Gomez, The role of population games in the design of optimization-based controllers: A large-scale insight, Carlos Ocampo.

Adrià Colomé Figueras, Bimanual robot skills: MP encoding, dimensionality reduction and reinforcement learning, Carme Torras.

Alex Goldhoorn, Searching and tracking of humans in urban environments with humanoid robots, René Alquézar and Alberto Sanfeliu.

María Laura Sarmiento Carnevali, Modelling and control of PEM fuel cells, Maria Serra and Carles Batlle.

2018

Zakaria Baroud, Modelling and observation of PEM fuel-cell systems: Application to the automobile transport field, Carlos Ocampo and Atallah Benalia.

Ye Wang, Advances In state estimation, diagnosis and control of complex systems, Gabriela Cembrano and Vicenç Puig.

2019

Masoud Pourasghar Lafmejani, On the fault diagnosis of dynamic system using set-based approaches, Carlos Ocampo and Vicenç Puig.

Pau Segovia Castillo, Model-based control and diagnosis of inland navigation networks, Vicenç Puig and Eric Duviella.

José Luís Sampietro Saquicela, Energy management of hybrid vehicles using economic model predictive control, Vicenç Puig and Ramon Costa.

Wicak Ananduta, Non-centralized optimization-based control schemes for large-scale energy systems, Carlos Ocampo.

Sara Siniscalchi Minna, Advanced wind farm control strategies for enhancing grid support, Carlos Ocampo and Mikel de Prada.

2020

Victor Vaquero Gomez, LiDAR-based scene understanding for autonomous driving using deep learning, Francesc Moreno and Alberto Sanfeliu.

Gerard Canal Camprodon, Adapting robot behavior to user preferences in assistive scenarios, Guillem Alenyà and Carme Torras.

Eugenio Alcalá Baselga, Advances in planning and control for autonomous vehicles, Vicenç Puig and Joseba-Jokin Quevedo.

Jenny Lorena Diaz Castañeda, Advanced energy management/control strategies for smart manufacturing systems, Carlos Ocampo.

Unnikrishnan Raveendran Nair, Control and energy management of energy storage systems for microgrids, Ramon Costa.

Fatemeh Karimi Pour, Health-aware predictive control schemes based on industrial processes, Gabriela Cembrano and Vicenç Puig.

Ely Repiso Polo, Collaborative social robot navigation in accompanying and approaching tasks, Anaís Garrell and Alberto Sanfeliu.

Jérémie Deray, Robust navigation for industrial service robots, Juan Andrade and Joan Solà.

2021

Soheil Sarabandi, Solving the nearest rotation matrix problem in three and four dimensions with applications in robotics, Federico Thomas.

Javier Garcia López, Geometric computer vision meets deep learning for autonomous driving applications, Antonio Agudo and Francesc Moreno.

Yashan Xing, Modeling and control for a fuel cell system, Ramon Costa and Na Jing.

Arya Shabani, Position analysis based on multi-affine formulations, Josep Maria Porta and Federico Thomas.

Antonio Rubio Romano, Fashion discovery: A computer vision approach, Francesc Moreno and Edgar Simó.

Mohamadou Nassourou, Robust economic model predictive control of smart grids, Joaquim Blesa and Vicenç Puig.

Albert Pumarola Peris, Bridging the gap between reconstruction and synthesis, Francesc Moreno and Alberto Sanfeliu.

Ricard Bordalba Llaberia, Kinodynamic planning and control of closed-chain robotic systems, Lluís Ros and Josep Maria Porta.

Martín Rafael David, Modelling and control of alkaline electrolyzers, Carlos Ocampo y Ricardo Sánchez.

Gregory Johann Conde Mendez, Modeling and control in open-channel irrigation systems, Carlos Ocampo y Nicanor Quijano.

APPENDIX B

IRI BOARDS

As explained in the main text, the IRI Board was created for the first time in 2006, with the election of Federico Thomas as director. Up to that date, the issues on the daily life of IRI had been addressed at periodical reunions of the robotics, control, and computer graphics group coordinators. In what follows, the IRI Boards along the years are listed. Their members are not paid for the hours they spend as representatives of the different collectives. Thus, this appendix is a sort of homage to their compromise in the functioning of the institute. The elected members of the Board are chosen every three years, more or less at the same time as the director, and are, besides the directive team, the department head, the PhD members representative, the PhD students representative, and the support personnel representative. The non-elected members of the Board are the general manager and the deputy director.

Not always do they complete the whole period in service. Promotion, e.g., a PhD students representative who presents his/her thesis, professional or personal reasons may make necessary to find a substitute, and not always one is found!

The people that have been occupying the different positions in the Board, some of them repeating at different positions are:

Director:
Federico Thomas (2006-2008)

Alberto Sanfeliu (2008-2014)
Juan Andrade (2014-2020)
Guillem Alenyà (2020-)

Deputy director:
Jordi Riera (2006-2008)
Juan Andrade (2008-2014)
Carlos Ocampo (2014-2018)
Júlia Borràs (2020-)

General manager:
Ana Canales (2006-2016)
Mª Isabel Míguez (2017-2018)
Victoria Osuna (2019-2021)
Diana Herrero (2021-)

Department head:
Carme Torras (Robotics) and Maria Serra (Control) (2006-2008)
Guillem Alenyà (2009-2011)
Francesc Moreno (2011-2014)
Pablo Jiménez (2014-)

PhD members representative:
Josep Mª Porta (2006-2008)
Enric Celaya (2008-2009)
Carlos Ocampo (2009-2014)
Vicenç Puig (2014-2016)
Antonio Agudo (2016-2017)
Guillem Alenyà (2017-2020)
Patrick Grosch (2020-)

PhD students representative:
Guillem Alenyà (2006-2007)
Sergi Hernández (2007-2008)
Attila Husar (2008-2010)
Júlia Borràs (2010-2011)
Sergi Foix (2011-2014)
Àngel Santamaria (2014-2017)
Víctor Vaquero (2017-2020)
Alberto Olivares (2020-)

Support Personnel Representative:
Miguel Allué (2006-2008)
José Luís Roncero (2008-2009)
José Lázaro (2009-2011)
Patrick Grosch (2011-2014)
Evili del Río (2014-2017)
Eduardo Ballesteros (2017-2020)
Sergi Hernández (2020-)

It should be mentioned that since September 2017 Neus Salleras has been appointed as link to the administrative services of the Faculty, and as such she also participates in all Board meetings.

APPENDIX C

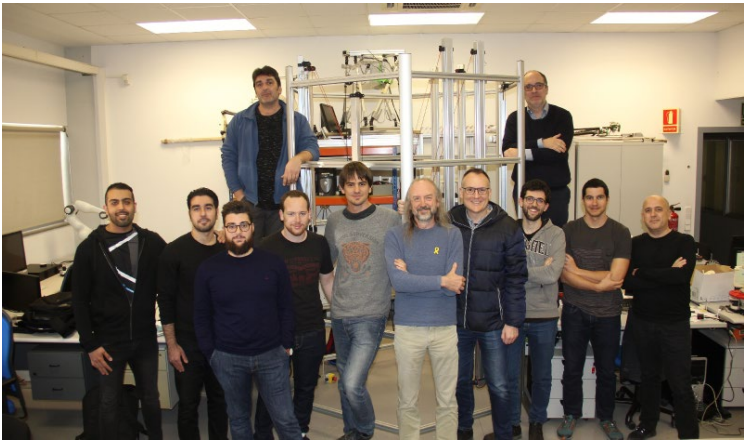
PERSONNEL

Photos made in 2019, before the pandemic

SUPPORT PERSONNEL

AUTOMATIC CONTROL GROUP

KINEMATICS AND ROBOT DESIGN GROUP



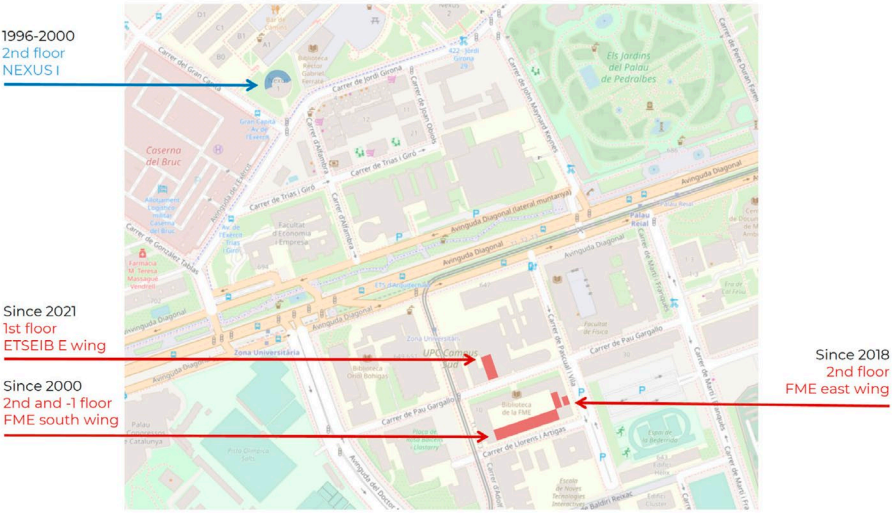
MOBILE ROBOTICS GROUP

PERCEPTION AND MANIPULATION GROUP

APPENDIX D

TEMPORAL EVOLUTION OF IRI SPACES

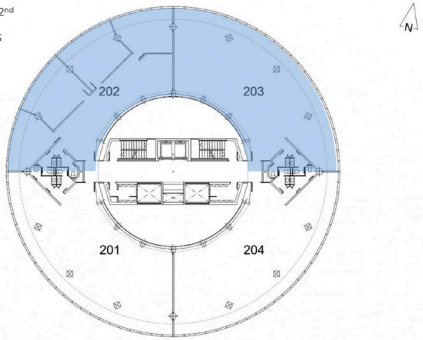
HISTORICAL EVOLUTION OF IRI LOCATIONS 1995-2021



The layout of the FME building corresponds to 2014 in all images, thus the modifications as for the walls etc, are not reflected.

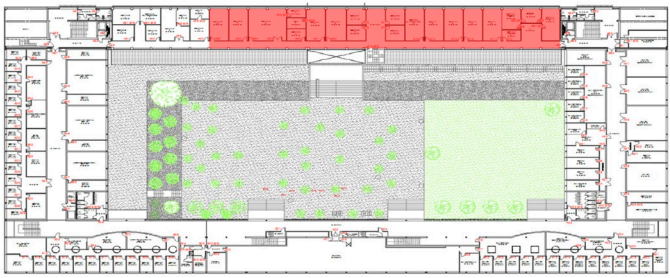
Years 1996-2000

IRI SPACE AT THE 2nd FLOOR OF THE NEXUS I BUILDING (~508 m²)



Year 2001

IRI SPACE AT THE 2nd FLOOR OF THE FME BUILDING (~675 m²)



Year 2007

IRI SPACE AT THE 2nd AND -1 FLOOR OF THE FME BUILDING (~918 m²)

Year 2010

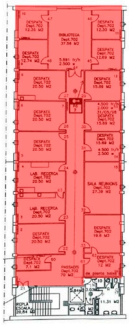
IRI SPACE AT THE 2nd AND -1 FLOOR OF THE FME BUILDING (~1150 m²)

Year 2018

IRI SPACE AT THE 2nd AND -1 FLOOR OF THE FME BUILDING (~1350 m²)

Year 2021

IRI SPACE AT THE 1st FLOOR OF E WING AT ETSEIB BUILDING (~394 m²)



Year 2021

IRI SPACE AT THE 2nd AND -1 FLOOR OF THE FME BUILDING (~1482 m²)