INSTITUTE FOR SYSTEMS AND ROBOTICS

Annual Report – 2005

Lisbon Pole

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OVERVIEW

The present report describes the activities carried out by the research elements of ISR-Lisbon. In 2005, the Associate Laboratory ISR-Lisbon, in partnership with the other 3 founding units (Centro de Estudos em Inovaçâo, Tecnologia e Políticas de Desenvolvimento from Instituto Superior Técnico - IN+, the Centro de Recursos Minerais, Mineralogia e Cristalografia – CREMINER, from University of Lisbon and Centro do IMAR from University of Azores), has been involved in a large number of activities in the frame of the Associate Laboratory (AL). The overall work carried out by the AL is described in a different report.

Since its foundation, ISR-Lisbon has given special attention to international cooperation in order to strengthen and broaden its scientific competence. Two types of cooperation are especially noteworthy: firstly, participation in R&D projects in conjunction with universities, research centers, and European businesses of note under the auspices of programs funded by the Portuguese Science and Technology Foundation, European Community and other agencies; and, secondly, training initiatives, primarily through master and doctoral programs. These initiatives have involved not only the Instituto Superior Técnico (IST) and the University of Algarve (UA) but also universities and research centers in Europe and the United States.

In 2005 we have continued our efforts in order to push theoretical developments in the fields of Marine Robotics, Underwater Acoustics, Mobile Communications, Computer Vision, Bio-robotics, Cooperative Robotics, Formation Estimation and Control and Aerial Robotics promoting international cooperation through joint projects; trying to reinforce the teams with full time and post-doc researchers; bridging the gap between theory and practice by pushing the collaboration with marine scientists, environmental experts and government agencies interested in the management of ocean resources and civil protection.

In 2005, ISR-Lisbon has offered several courses in the Doctoral and Master Programs in Electrical and Computer Engineering of IST, as well as other post-graduate level courses. Internal seminars were organized in a weekly basis, and a monthly seminar was organized together with the Mathematics Department of IST. The courses and seminars were attended by a large number of Ph.D. students and faculty.

In 2005, 151 senior and junior researchers have developed their research activities within ISR (Lisbon Pole). These included 33 professors, 1 Principal Researcher and 1 Assistant Researcher, 4 post-docs, 47 Ph.D. Students, 13 M.Sc. Students and 30 undergraduate research trainees. As a consequence of the efforts for internationalization, 1/3 of the Ph.D. students at ISR-Lisbon in 2005 are foreigners. Additionally, ISR researchers have supervised 7 graduate students enrolled in foreign universities. Also, young licentiates from several European countries have come to participate in short and medium term research initiatives.

During 2005, the institute researchers have been involved in a large number of national and international R&D projects, financial resources being provided at a national (FCT, ICCTI, AdI, Ciência Viva, private companies) and international level (EU, ESA and others), contributing to increase the international visibility of the institution. Three new projects funded by FCT started and new proposals were submitted to EU. As a result of these activities 5 M.Sc. and 3 Ph.D. theses were concluded, 2 books were edited, 6 papers where published in books, 21 papers were published in known international journals, and 67 papers presented at prestigious international conferences. Steps keep being taken to encourage researchers to increase the publication of their research results in archive journals.

The participation in editorial boards of international journals, in the program committees of international conferences of high reputation and the delivery of invited talks in international conferences was also very active.

In 2005 ISR organized four scientific events that largely contribute to enlarge the international visibility of the institution: the IbPRIA2005 – Iberian Conference on Pattern Recognition and Image Analysis attended by 180 researchers from 38 countries, the RobotCub Workshop with about 50 participants, a special workshop on Cooperative Robotics integrated in the IEEE International Conference on Robotics and Automation and the HAREM2005 a workshop on Human Activity Recognition and Modeling. Additionally, and following a long tradition in outreach activities, a short course for high-school students on the Construction of a Soccer Robot was offered.

The absence of a clear commitment from FCT that funding will be available in a regular basis, and the shortage of funds received in 2002, 2003 and part of 2004, prevented us from hiring new post-doc researchers and technical staff up to the end of 2004. In 2005, and regardless of the unpredictability of fund availability, ISR-Lisbon

launched the calls to hire, for a three year period, four researchers with Ph.D. One of such researchers started working with us on July 2005.

As in previous years, we urge again the host institution, IST, to recognize the research and graduate advising contributions of the faculty through the assignment of different classroom teaching loads and through the increase of administrative and technical support for all our laboratories. This is particularly important, as a large number of ISR-Lisbon researchers that are faculty at IST have heavy allocated duties, both in scientific and in management terms, in the frame of IST governance.

Since its foundation in 1992, ISR-Lisbon was directed by Prof. João Sentieiro whose vision and leadership steered ISR-Lisbon along lines of excellency, visibility and internationalization that allowed to consolidate its actual national and international reputation. At the end of 2005, our Director was nominated as the President of the Portuguese Science and Technology Foundation (FCT) and thus assumed higher responsibilities in the management of the Science and Technologies policies in Portugal. As the elected Director and on duty since January 2006, I wish to express my deep appreciation for the major role that our former Director played in our past history and hope that we will be able to carry on the scientific competence and excellency that we always pursue.

Many people have contributed to this report and I would like to herein acknowledge their efforts. I hope that the report is of use to all its readers and to the agencies and foundations that support our activities and that it proves the importance and quality of our on-going activities.

Isabel Ribeiro, Director, ISR-Lisbon
March 2006

1. ISR IN NUMBERS

	2002	2003	2004	2005
Research Team				
University Professors	27	29	28	33
Principal Researchers	01	01	01	02
Post-Docs	07	08	03	04
Ph.D. Students	44	44	45	47
M.Sc. Students	26	24	24	13
Research Engineers/Assistants			10	21
Undergraduate Students	39	26	34	30
Total	144	132	145	151
Research Projects	39	41	32	33
Doctoral theses concluded	10	06	03	03
Master theses concluded	05	06	08	05
Publications				
Books (as author)	02	00	00	00
Books (as Editors)	00	00	00	02
In Books	12	03	06	06
In International Journals	29	26	26	18
In National Journals	01	01	01	01
In International Conferences	74	58	66	64
In National Conferences	09	14	06	04
Technical Reports	21	28	30	28

2. RESEARCH TEAM AND INTERESTS

2.1 MEMBERS AND COLLABORATORS

THEORY GROUP:

Michael ATHANS, *Principal Researcher*
Luis Torres MAGALHÃES, *Full Professor (IST)*

INTELLIGENT SYSTEMS:

Carlos PINTO-FERREIRA, *Associate Professor (IST)*
Pedro LIMA, *Assistant Professor (IST)*
Luis CUSTÓDIO, *Assistant Professor (IST)*
Sónia MARQUES, *Adj. Professor (IPS), Ph.D. St.*
Rodrigo VENTURA, *Teaching Assistant (IST), Ph.D. St.*
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Abdolkarim PAHLIANI, *Ph.D. St.*
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Vasco PIRES, *M.Sc. St.*
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Constança SOUSA, *M.Sc. St.*
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João COSTAL, *Research Assistant, EUCLID RTP9 grantee*

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João OLIVEIRA, *Assistant Professor (IST)*
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ADMINISTRATIVE STAFF:

Filomena VIEGAS
Loic BAMDÉ
Ana Margarida SANTOS
Ana Maria ESTEVES

2.2 CURRENT RESEARCH INTERESTS

The Lisbon pole of ISR is internally organized in 8 laboratories / groups. In this section the main research interests of each one of the laboratories / groups are briefly described.

2.2.1 INTELLIGENT SYSTEMS LAB (IS)

Whenever a robotic agent or a multi-robot team evolves in a particular environment, a fundamental issue concerns how are the robot(s) decisions planned and made, based on the available information from internal models and sensor data. This is related to how to provide the robotic *machine* with *intelligence*, and raises underlying philosophical questions such as:

- What is the nature of the intelligence in robotic agents?
- How should we study it when several robotic agents interact and cooperate?

The Intelligent Systems Laboratory driving theme is the Research and Development on Multi Robot Systems (MRS), namely addressing cooperative task planning, task allocation and coordinated task execution, but also related topics, such as robot formation guidance, navigation and control. We have brought together people with a common background on Systems Theory, with different approaches to modelling, analysis and implementation of Intelligent Systems, mainly coming from the following fields:

- **Artificial Intelligence**, with a focus on multi-agent systems, either virtual (e.g., web agents) or with a physical body (e.g., robots), and special interests on knowledge representation and reasoning, organizational issues, distributed decision making and social relations; and

- **Control**, where the growing complexity of existing systems to be controlled, as well as the problems related to integrating design and real-time operation of decentralized control systems, many of them distributed in nature - large plant process control, robots, communication networks - are exciting challenges,

to discuss and come up with novel methods applicable to MRS.

To achieve our goal, we develop research on rational agents, which either attempt to minimize a cost function to reach their goals - such that an optimal balance among different subsystems is attained - or use logic based reasoning to attain some goal(s), given the description of the world and their knowledge base. Also, we investigate methodologies to design emotion-based agents whose courses of action are entrenched in built-in or learnt associations between stimuli and the corresponding somatic-based evaluation of desirability. This measure of desirability can be estimated for the agent itself and for others when a social behaviour is established.

In the sequel, we provide some detail on the research and development topics covered by the Lab members activity in 2005, as well as on the major results achieved.

Hybrid and Discrete Event System Models of Robotic Plans - Most of the existing MRS models are not based on formal approaches. Typically, only a small number of behaviours, tailored to the task at hand, are considered. Furthermore, the emergent overall behaviour when using self-organizing system approaches is usually not predictable, as there is no constructive theory of emergent behaviour. This raises the question of how to design a MRS which is goal-oriented, therefore being able to perform a given mission while meeting a set of specifications. We claim that formal plan modelling methods for robotic tasks enable a systematic approach to modelling, analysis and design from specifications. This is clearly an advantage in goal-oriented systems, but can prove useful in behaviour-based systems as well, where using self-organizing approaches frequently leads to unpredictable behaviour, a certainly undesirable feature for applications requiring safety, robustness and performance guarantees, as in a search and rescue scenario. Moreover, despite its inherent complexity, such methods allow to model, up to a certain dimension in the number of involved behaviours, events and conditions of world components, scaling up from problems with a limited number of behaviours, whose coordination one can design “by hand”, to realistic applications with a considerable number of behaviours, where coordination solutions are not intuitive and require algorithms to handle the large

behaviour space. Recent attempts to handle planning under uncertainty have used Markov Decision Processes (MDPs) and Partially Observable MDPs (POMDPs) as a modelling basis. A potential advantage of starting with a Discrete Event model instead is the natural design process and the complexity reduction (with respect to MDPs and POMDPs), since a dynamic model is known and the search for optimal actions can be made in a reduced space. As an example, in POMDPs, the policy maps the probability density function (pdf) over the set of all possible states into an action; if we use a Discrete Event Observer for a Discrete Event System with unobservable events, we will know that, at a given step, the probability of being in a given state is zero, and the policy domain will be a pdf over the set of states with non-zero probability. This formal approach to MRS analysis and design from specifications, and some of its resulting applications, e.g., to soccer and search and rescue robots, is included in [14]. Specific work on the analysis of navigation controllability for teams of heterogeneous mobile robots was presented on [11].

Cooperation takes place when, in addition to coordination, formal teamwork models are used [12]. Petri nets (PNs) are especially interesting to model teamwork, as communication signals exchanged by the cooperating teammates often involve synchronization events and transition between discrete states. In PNs, the state information is distributed among a set of places which capture key conditions governing the system, and PNs have increased modularity for model-building. This way, one can build a PN model for the plan of each of the team generalized robots, and then add commitment and synchronization mechanisms, represented by Petri net modules, to establish a relation among the individual plans. Work on these topics has been pursued during this year, but it is yet unpublished.

(Cooperative) Reinforcement Learning – Reinforcement Learning has been widely applied in recent years to a wide number of task planning problems concerning a single agent. Most of those concern simulated environments and / or virtual agents, modelled as MDPs. New challenging problems arise when one considers real robotic agents, where partial and noisy observations are more realistic, leading to PODMP models, as well as when a robot team, acting cooperatively, attempts to learn and coordinate each individual robot plan. In fact, reinforcement learning can be considered as an approach to the solution of stochastic decision making problems, in the more difficult situation where the model structure may be known, but not its parameters (e.g., transition probabilities in MDPs, as well as observation pdf in POMDPs). Furthermore, cooperation between agents / robots introduces new interesting issues, such as what should teammates share (e.g., policies, state values, world models) [44, 65, 108] or whether they should use game theory to determine suitable equilibria [38], for the coordinated execution of robotic tasks.

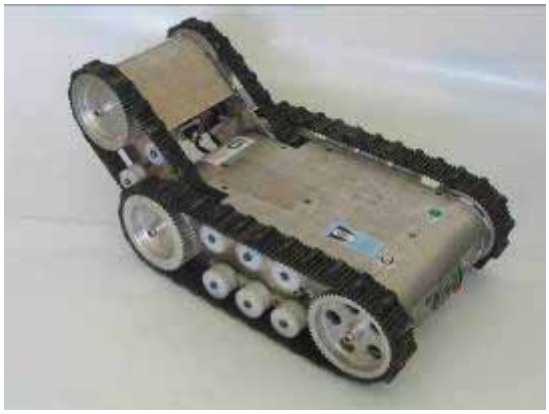
Formation Feasibility, Guidance, Control, Navigation and Coordination – Formation control is currently a hot topic on most Control conferences and journals. Most of the work focus on *rendez-vous* problems, i.e., taking a set of robots to a pre-defined geometry (this is related to guidance problems, where optimal collision-avoiding trajectories are computed for this purpose), fine control, i.e., to keep the specified geometry, dynamically changing the geometry over time and also on making the formation geometry specifications flexible enough to avoid collisions with obstacles and / or within team members. One relevant issue, prior to controlling or guiding robot fleets, is to ensure that the geometric constraints imposed to the robots, given their kinematics, are feasible. This problem was solved in [20], where algebraic conditions that guarantee formation feasibility given the individual agent kinematics are introduced. This framework also enables one to obtain lower dimensional control systems describing the group kinematics, while maintaining all formation constraints.

A considerable amount of work on Formation-Flying Spacecraft Guidance, Navigation and Coordination (GN&C) was also spent during this year, within the framework of the ESA project concerning a mission involving three spacecraft flying in formation for high resolution distant planet observations. The group developed an integrated approach to GN&C where an algebraic closed-loop Guidance algorithm, based on Pontryagin's maximum principle, was introduced, minimizing the propellant consumption and ensuring collision avoidance [63]. The Navigation algorithm estimates the full relative state of all the spacecraft using a full-order decentralized filter, based on an Extended Kalman Filter for local measurements, and on Covariance Intersection for the fusion between local state estimates and estimates communicated by other spacecraft, eliminating EKF divergence problems [111]. The overall coordination of the formation-flying spacecraft mission, including different Guidance and Navigation modes along the orbit, and other actions such as taking high-resolution pictures of distant planets when the fleet traverses the appropriate mode, is performed by a software architecture introduced in [111].

Emotion-based Agents - emotion-based agents are entities whose behaviour is guided by taking into account first a rough evaluation of a stimulus goodness and badness, and then an identification of the stimulus based on past experiences. A complementary goal for this research is to study how an emotion-based architecture might be articulated with a classical rational-based architecture.

Applications - the group is currently interested in applications to *Soccer Robots*, *Rescue Robots*, *Manufacturing Systems*, and *Satellite Formations*. Multi-robot systems were used to manage supply-chain problems [22]. Four new multi-sensor omnidirectional motion robots were built within the frame if the SocRob project, and can be used for general purpose research on single and multiple robot systems. A tele-operated search-and-rescue robot, nicknamed RAPOSA, was designed and built, in consortium with an ISR spinoff company, to help fire brigades on search and rescue operations. These are described in more detail within the Projects section.

Four new omni-directional soccer robots, developed together with Portuguese companies IdMind and ServiLog, within the framework of the FCT Project SocRob



RAPOSA Rescue robot, developed together with Portuguese companies IdMind and SetPontes, within the framework of the AdI Project RAPOSA

2.2.2 COMPUTER AND ROBOT VISION LAB (VISLAB)

When a camera is moving in a static (or dynamic) environment, the image sequence conveys information regarding the scene / objects structure and camera / objects motion. Computer vision and image analysis allow the extraction of a variety of information of the observed scenes that enable a large number of applications ranging from 3D reconstruction, motion analysis, video surveillance and robotics.

The research conducted at the Computer and Robot Vision Lab - Vislab has two main goals. On one hand, there is the goal of developing methodological tools of computer and robot vision. On the other hand, such methodologies are demonstrated in challenging applications that call for such new tools. The research is organized in two main lines:

- **Vision Based Control and Navigation**
- **3D Reconstruction, Motion Analysis and surveillance**

a) Vision Based Control and Navigation

In this topic, we address the fundamental problems of understanding what *relevant* information can be extracted from an image sequence to *control* an artificial system (robot) in order to perform a *given task*. This has been a long standing research line of the Vislab including the control of extremely varied systems:

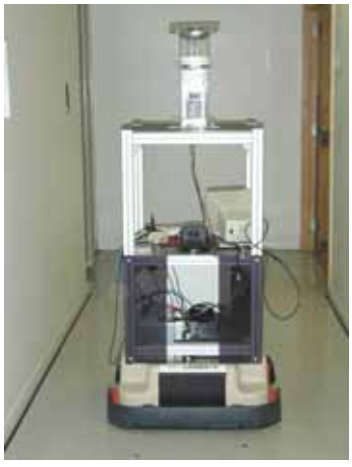
- One distinctive aspect is the search for alternative imaging geometries, often inspired after biological findings. Extensive work has been carried out in the domain of using omnidirectional images for navigation and control as well as for map building for indoors robots;

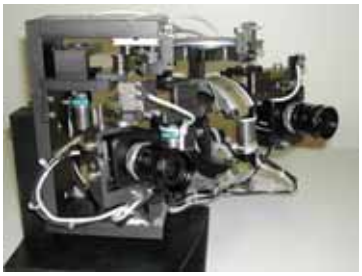
- vision based navigation for land, aerial or underwater vehicles. When the camera moves in the 3D space, the interplay between the camera's degrees of freedom, the scene structure and video signal is significantly richer. Example applications have focused on lighter than air blimps and underwater vehicles, in the context of European Research Projects;

- In addition, we have pursued the usage of non-metric maps for navigation like topological maps for structured environments and video mosaics for underwater navigation;

- the active control of binocular heads;

- cooperative localization and mapping (using vision).





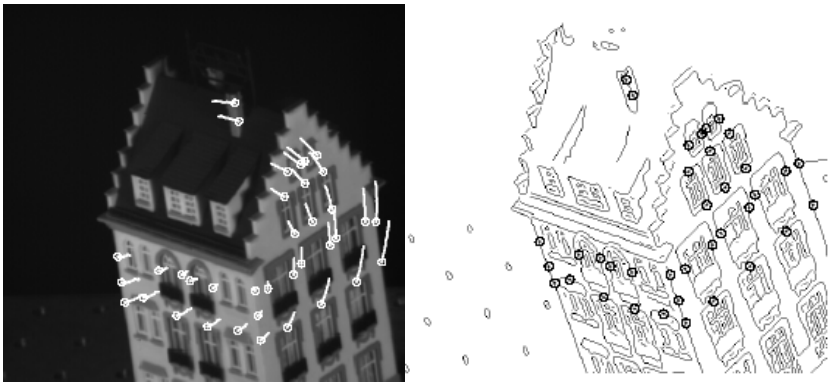
This line of research has evolved towards more cognitive systems, where the vision systems learn from the observations over long periods of time. One such example lies in the area of video surveillance where the goal is to understand human behavior from video observations and adjust the system's performance to the actual observation context. Another example is the study of techniques allowing a complex system to develop and adapt over long periods of time.

The context for this line of research is that of the development of humanoid robots able to learn how to perform complex tasks through observation. The work in this domain has been carried out with collaboration with neuroscientists and developmental psychologists. On one side, physiology tells us how the perceived information is processed in the brain and which brain areas are responsible for certain (visual) tasks.

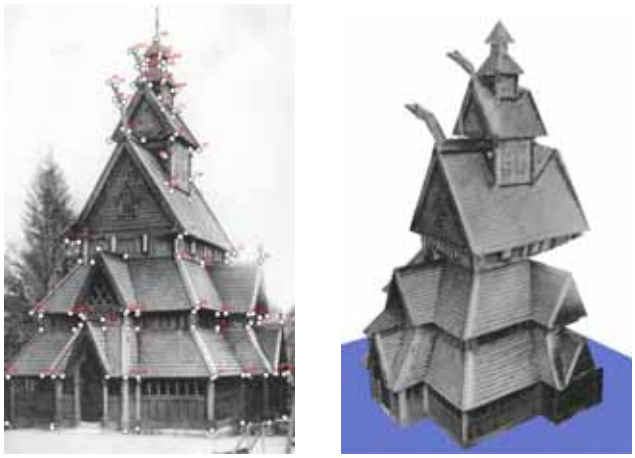
Our main experimental platform for this line of research is Baltazar, a humanoid robot with an articulated arm/hand and a binocular head (see photo). Research on sensory-motor coordination has led to the development of methods where the robot learns how to calibrate itself through the exploration of its own body. To a large extent, this approach is inspired by the first few months of life of human infants. Then, the robot starts exploring the surrounding objects. Finally, in the most advanced phase, the robot will interact with and learn from people.

b) 3D Reconstruction, Motion Analysis and Surveillance

The theme of *3D motion Analysis and Reconstruction* is devoted to the geometry of retrieving information about the scene structure or camera motion from video sequences. Work has addressed the problem of estimating the 3D motion of a camera from an image sequence. Several visual cues were exploited for this purpose: the visual motion and occlusions. Regarding 3D reconstruction, work has focused on developing optimal approaches for matching image features, which is a fundamental step in most 3D vision systems. In addition, the depth estimation process has been formulated in an optimal way by itself.

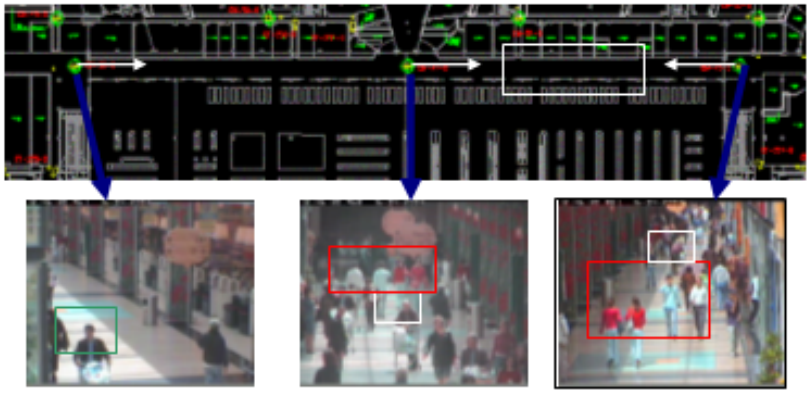


Another line of research has been the reconstruction of structured scenes (e.g., buildings) where geometrical constraints can be explored to facilitate or improve the quality of the reconstruction.



Another vibrant line of research is that of video surveillance with a particular emphasis on cognitive vision systems. As the number of CCTV cameras deployed in public spaces grows very rapidly, it becomes an

overwhelming task for humans to monitor all those video streams. Instead, there is a need for artificial systems able to learn from observation and characterize human actions. Such systems would only call for the security operator attention when an alarming event was observed. The research carried out in this domain included the definition of a number of feature detectors and the design of methods for feature selection and for the classification of human activities.



Research in all these topics has been carried out both at the level of the fundamental methodologies and also for applications. As the knowledge in these various aspects matures inside the group, research projects have been proposed, including national and European Projects.

2.2.3 MOBILE ROBOTICS LAB (LRM)

The Mobile Robotics Lab activities focuses on the research, development and testing of robotic tools applied to the control and navigation of autonomous mobile robotics.
In this Laboratory we are particularly interested in the issues of:

Mobile robot navigation, in structured and semi-structured environments,
Cooperation/collaboration among multiple robotic devices,
Robotics and information systems,
Robotics applications.

Mobile robot navigation: Study of navigation methodologies for the operation of mobile robots in structure and semi-structured indoor environments, including environment representation, obstacle detection and avoidance, motion control and localization. Different sensors are used, namely ultrasound, laser and vision. The group is most interested in the establishment of new sensor and world representations aiming at simplifying the navigation tasks, namely to overcome the absolute localization required in most tasks. The study of probabilistic approaches for the Simultaneous Localization and Map Building, SLAM, in outdoors environment, together with hybrid and topological environment representation, aiming at outdoors operations is currently under study.

Cooperative robotics: Study of the control of multiple heterogeneous robots acting together towards the fulfillment of an assigned task. Behavior-based approaches to the control of each single robot and multi-robots are considered using tools from algebraic group theory. These led to conceptual control architecture of hybrid nature, with a supervisor modeled by a finite discrete automaton and a set of classes of continuous models modeling robot motion. A distinctive feature of these continuous models is that they accept (in the sense that an assigned mission can be successfully executed) a broad range of robot trajectories.

A different addressed issue relates with the problem of coordination of multi-agent systems in the absence of communication. In particular, considering a set of robots moving in an environment, we describe the individual behavior of each robot if, as a whole (team), the group has a global goal that requires the coordination of the robots in order to be achieved. We consider that the robots are moving in an environment described as a topological map. This allows to cast the coordination problem without communication as a stochastic game and to apply reinforcement learning algorithms to achieve coordination. In particular, we address the study of convergence of several reinforcement learning algorithms to optimal Nash equilibria under conditions which can be understood as the multi-agent counterparts of those ensuring convergence in

single-agent reinforcement learning algorithms. We also address the problem of partial observability under the additional assumption of limited sensorial capabilities.

Cooperative perception and localization are key issues in a multi-robot system, where the overall sensorial capabilities with spatial and temporal distribution are expressed to solve, with advantage, the navigation problem of isolate robots and the entire team. Experiments are being carried out on a team of four Sony dogs.

Robotics and information systems: Information systems are one of the cornerstones of most of the modern organizations. Furthermore, the use of CASE tools in organizations management/operation led to the development of abstract modeling languages of which one of the most widely used is UML (Universal Modeling Language). The biological inspiration has been used in many areas of robotics, such as sensors and robot control architectures. Furthermore, the recent explosion of cooperative robotics is also absorbing paradigms from social evolution models to minimize the complexity of the problem. A similar approach was followed to design a robot control architecture based on a business modeling framework. Unlike the classical approach, this robot control architecture is defined for each mission assigned to the robot and it is revised each time an event in a pre-specified set is triggered. It is also expected that the overall methodology can be applied to robot teams.

Robotics applications: The study of the theoretical issues in robotics is often motivated by the problems arising in practical applications. The range of applications of robotics endorsed by current state of the art technology, namely electronics and software technologies, is growing. Social and/or economical arguments can easily support the research on robots for specific applications. Moreover, applications often require the integration of different systems, most likely built around different technologies, and hence motivate the research in architectural aspects of robotics.



2.2.4 SIGNAL AND IMAGE PROCESSING LAB (SP)

- Statistical signal processing on manifolds: modelling, filtering, performance bounds;
- Wireless communications: space-time codebook design for non-coherent receivers;
- Channel estimation and equalization;
- Fast and numerically stable algorithms for adaptive filtering;
- Underwater digital communications;
- Time-reversal acoustics;
- Array processing;
- Genomic signal processing;
- Software-defined radio;
- Image and Video Analysis;
- Digital Video Representations;
- Multimedia Signal Processing.

SP at University of Algarve

Broad Areas of Research:

- Underwater acoustic signal processing;
- Underwater communications;
- Inverse problems;
- Estimation and optimization.

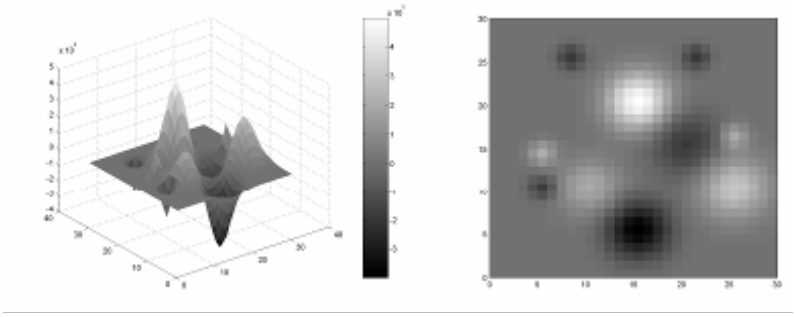
Applied Research:

- Acoustic Rapid Environmental Assessment;
- Acoustic and Non-acoustic Data Assimilation;
- High Frequency Acoustic Propagation;
- Underwater Communications via Environmental-based Time-Reversal;
- Environmental-based Source Localization;
- Development of Acoustic-Oceanographic Buoy Systems.

2.2.5 EVOLUTIONARY SYSTEMS AND BIOMEDICAL ENGINEERING LAB (LASEEB)

The research work of this group focus on biologically inspired new algorithms and paradigms for search and optimization and biomedical signal and imaging processing algorithms. The potential of the results have been demonstrated in applications. A few recent results will be presented below.

In the Evolutionary Algorithms: The extension and validation of adaptation of the Olive Fly Model (*Bractocerao olea*) using Evolutionary Approach has captured new interest, namely with Bayer Department of Plant Protection, where a field validation program is currently on going. A new topic of research in this area is the use of Swarm Stigmergy and Self-organization paradigms under varying environment and population size. More efficient strategies have been devised for dynamic environment with objective switching. An example result is shown in the figure below:



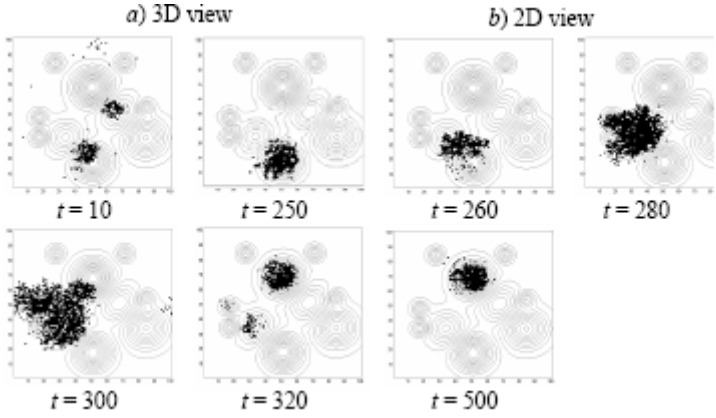
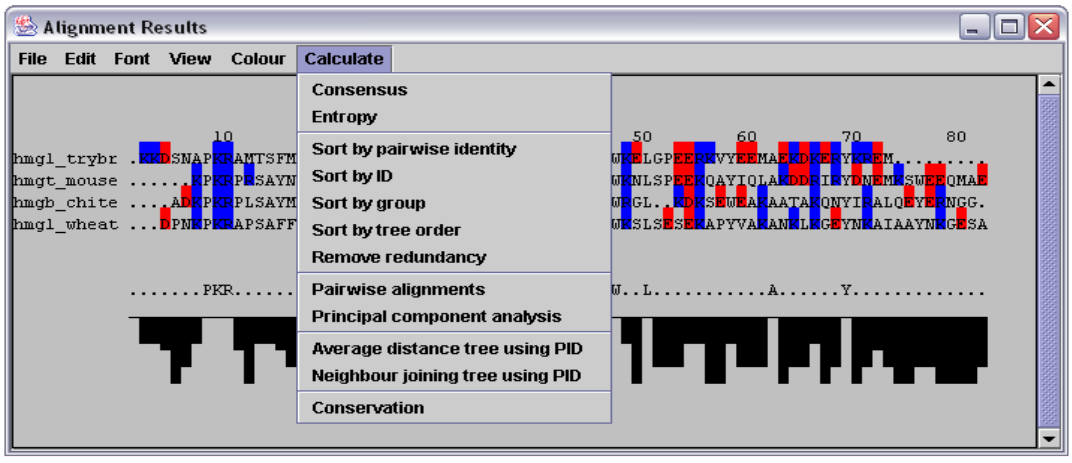
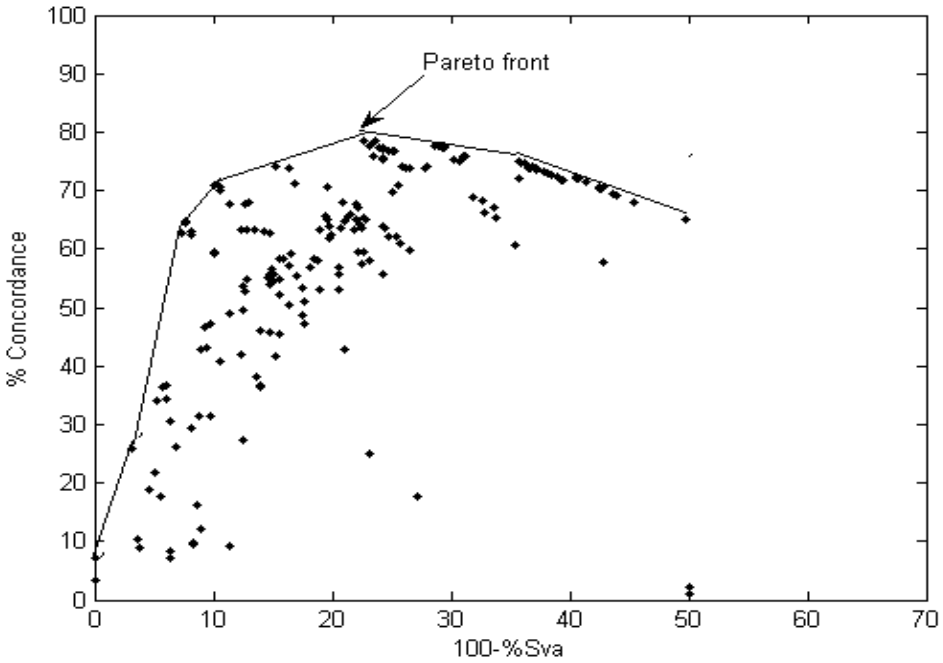


Fig. 1. SVPS evolving on a complex multimodal function seen in *a-b*) [13,29,31]: the self-organized swarm emerges a characteristic flocking migration behavior between one deep valley (south region) and one peak (north region), surpassing in intermediate steps (*Mickey Mouse* shape at *t* = 300) some local optima. Over each foraging step, the population self-regulates. From *t*=0 to *t*=250 the swarm is induced to search the lowest valleys of the landscape. After *t*=250 the task changes (target peak moves to the north of the territory) and the swarm must find the higher values of the function. Check for detailed results in [13].

A new hybrid evolutionary algorithm with dynamic programming for multiple protein sequences alignment has been implemented and a screen shot of the program output is shown below:



In the Biomedical Engineering area, the group has contributed to the research and normalization in young children population of the Cyclic Alternating Pattern paradigm for NREM sleep microstructure. A Pilot study on Excessive Daytime Sleepiness has been started in collaboration with the Stadual University of São Paulo. The Classification and Dynamic organization of Phasic Events in the Sleep EEG code named ascending Activation is currently applied to the EDS project. An Evolutionary Algorithms (ARGA) adapted rule based classification systems for automatic CAP analysis using wavelet decomposition has reached its final stage of development. Recent results show that the classification agreement with the golden reference is over 80% using the CAP group test set. The concordance and sensitivity plot is show below:



Also under development is an evolutionary color constancy algorithm based Gamut Mapping paradigm, which is able to perceive the true colors and discount the illumionation from a scene viewed under light having spectral compositions.

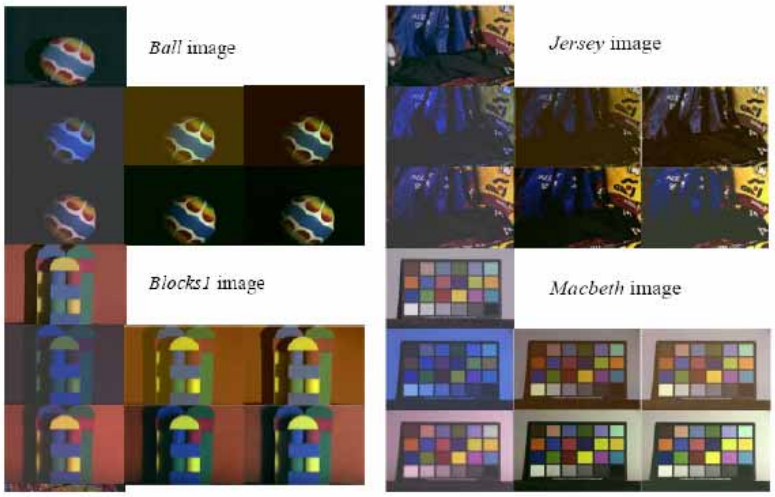


Fig. 3. IGA-GM solutions on different illuminants. Figure is divided in horizontal bands for each scene. First column first line: target image; second line first column: image under "solux_4700+3202"; second line second column: IGA-GM; second line third column: "IGA-GM + intensity correction"; third line first column: image under "syl_wwf"; third line second column: IGA-GM; third line third column: IGA-GM + intensity correction.

2.2.6 DYNAMIC SYSTEMS AND OCEAN ROBOTICS LAB (DSOR)

There has been tremendous progress towards the development of autonomous robots for ocean exploration and exploitation. Autonomous robots do not place human lives at risk and allow access to otherwise unreachable regions of the ocean and its interfaces with the earth's crust and the atmosphere. Equipped with advanced systems for navigation, guidance, control, and scientific data acquisition, they hold great potential to drastically simplify the task of acquiring marine data fast and in a cost-effective manner, without constant supervision of human operators. As such, they are steadily becoming the tool par excellence for ocean exploration and exploitation. Whereas most of the work done so far has been focused on the operation of surface and underwater vehicles (**ocean segment**), a trend is clearly visible where autonomous air vehicles (**air segment**) start to play an important role in ocean-related studies. Namely, by working either as single units (e.g. mapping of coastal areas and sand dunes) or in cooperation with marine vehicles (e.g. as transmission relays or as scouts to re-direct the operation of the latter).

Over the past years, the ISR/IST through its Dynamical Systems and Ocean Robotics Laboratory (DSORL) has been involved in a number of projects that have culminated with the deployment and operation of marine robots at sea. The European *MARIUS/SOUV* project, coordinated by ISR/IST, witnessed the development of the first civilian AUV (Autonomous Underwater Vehicle) in Europe. In the scope of the EU DESIBEL project coordinated by IFREMER, ISR/IST contributed to the development and at sea testing of an underwater shuttle for the transportation of benthic laboratories. The European *ASIMOV* project, also coordinated by ISR-IST, led to the development of advanced systems for the coordinated operation of the INFANTE AUV and the DELFIM ASC (Autonomous Surface Craft), both designed and built in Portugal under the auspices of the FCT. More recently, in the scope of the Portuguese *CARAVELA* project coordinated by IMAR-DOP/UAzores, the ISR-IST participated in the development of an autonomous research vessel for long range open ocean operation. The project is a landmark in the development of future ocean platforms that can replace normal research vessels in the more repetitive types of missions. During the past three years, ISR/IST has embarked in the development of three new marine robots: i) the DREAM ROV, for operations down to 1000 meters, in cooperation with CREMINER and the Faculty of Sciences of the University of Lisbon; ii) MAYA, a miniaturized AUV for commercial and scientific applications, in cooperation with IMAR-DOP/UAzores and the National Institute of Oceanography, Goa, India, and iii) the DELFIM_X ASC, an improved version of the DELFIM ASC that will serve as a platform to carry IRIS, an automatic surveying tool for the inspection of rubble-mound breakwaters, above and under the waterline.

Over the past three years, as a natural consequence of a longstanding collaboration program with the Department of Aeronautics and Astronautics of the Naval Postgraduate School of Monterey, California, USA, the ISR/IST has also started to apply some of the methodologies and technologies developed for ocean vehicles to the control of air robots (helicopters). This is justified in view of the increasing interest worldwide in the use of unmanned aerial robotic vehicles to perform airborne surveying tasks. As part of this effort, the ISR/IST has been instrumenting an unmanned robotic helicopter that will serve as an advanced platform for NGC (navigation, guidance, and control) system design, implementation, and testing. The platform is based on an industrial radio controlled helicopter that was equipped with a distributed real time computing network, a reliable wireless communication system, and sensing devices. The activity pursued in this area is well rooted in scientific applications that require the use of autonomous air robots to accurately map coastal areas subjected to erosion, using airborne laser altimetry. In particular, project ALTICOPTER funded by the FCT envisions the use of a helicopter to map sand dunes along the Portuguese coast.

Thee vehicles and tools that are built at IST/ISR play the dual role of i) *advanced testbeds* to field test new system theoretical concepts and hardware / software architectures for autonomous vehicle control, and ii) *platforms for actual operations at sea*, effectively paving the way for a fruitful symbiosis between marine science and technology.

In spite of the achievements made in the field of marine-related robotics, much work remains to be done to before such vehicles become ubiquitous instruments in the marine science "toolbox". Meeting some of the challenges for advanced vehicle systems design as a contribution towards the development of faster, cheaper, and more efficient methods for the exploration and exploitation of the ocean, is one of the key objectives of the DSORL-ISR/IST. This objective called for the definition of a **threefold research and development effort that addresses theoretical and practical engineering issues, as well as issues related to the interplay**

between marine sciences and marine technology. The main thrust of the work done at the DSORL is therefore directed along the following lines of action:

- Contributing to furthering the knowledge in the general area of **dynamical systems theory**, with a special focus on **nonlinear control theory** and **robust / adaptive control** of highly uncertain systems.
- Developing new analysis and design tools in the areas of **navigation, guidance, and control (NGC)** and applying them to the development of advanced systems for autonomous marine and aerial vehicles.
- Investigating algorithms for trajectory tracking, path-following, and terrain-following control.
- Studying and developing algorithms for **feature-based navigation of autonomous underwater vehicles** by exploiting the use of acoustic bathymetric terrain data and geomagnetic data.
- Developing strategies for **coordinated control of multiple autonomous vehicles** (in the presence of severe communication constraints) that are well rooted in nonlinear system theory and **networked control.**
- Advancing the development of software and hardware for the development of prototypes equipped with real-time operating systems for vehicle positioning, navigation, guidance, and control, as well as **Mission Control.**
- Developing tools for **acoustic and scientific equipment interfacing;** performing actual missions at sea to transition from the laboratory to the real world and to foster the **symbiosis between marine science and technology.**

This work is being carried out in cooperation with institutions worldwide. Especially relevant are the cooperation links forged with India, Brazil, Norway, France, and the USA. At the same time, the group has been pursuing the execution of missions at sea to transition from the laboratory to the real world and to foster the *symbiosis between marine science and technology*. Missions take place in continental Portugal in the areas of Lisbon and Sines, and nearly every summer in the Azores in cooperation with the IMAR/DOP/UAzores using the prototype robots developed at ISR/IST.

Cooperative Links

The DSORL is involved in a number of projects and concerted actions with national and foreign institutions with the objective of advancing the development of engineering methodologies and equipments to the point where they can be used as versatile tools to expand our understanding of the oceans. Representative institutions include the following:

- Department of Mechanical Engineering and Aeronautics, Naval Postgraduate School, Monterey, CA (USA).
- Center for Control Engineering and Computation at University of California, Santa Barbara; CA, USA.
- Istituto Automazione Navale, Genova (Italy).
- National Institute of Oceanography, Goa (India) – a memorandum of understanding has been signed between NIO and ISR.
- Department of Engineering Cybernetics, Norwegian University of Science and Technology (NTNU), Trondheim, Norway.
- IFREMER (French Institute for Ocean Exploitation), France.
- Department of Electrical Engineering of the University of Genova (Italy).
- Department of Innovation Engineering, Univ. Lecce (Italy).
- Department of Mechatronics, University of São Paulo (Brazil).
- IMAR/DOP/UAzores - Department of Oceanography and Fisheries of the University of the Azores (Portugal).
- CREMINER – The Geology Center of the Faculdade de Ciências da Universidade de Lisboa (FCUL).
- Instituto Geológico e Mineiro (IGM-Geological Survey of Portugal)
- Laboratório Nacional de Engenharia Civil (Portugal).

Privileged links have been established with the IMAR/DOP/UAzores and CREMINER/FCUL, under Theme A (Techniques for Ocean Exploration) of the Laboratório Associado (Associated Laboratory) that is coordinated by ISR/IST. At a technological level, this concerted effort is in line with the current trend worldwide, aimed at the development of ocean sampling networks (OSN) providing a nested ocean

observation capability through the coordinated control of many, mobile, networked sensor platforms. This trend shows clearly that advancements in marine robotics, communications, and information systems are steadily being brought to bear on the development of technologies to enable safer, better, faster, and far more efficient methodologies for the study of the oceans. At the same time, the plethora of engineering problems that must be tackled and solved in the context of ocean research pose considerable challenges to theoreticians and system designers.

Main Lines of Research and Development

The work reported addresses theoretical and practical issues. Striking an appropriate balance between the two factors is a hard task that requires the cooperation of many researchers / engineers, with expertise that covers a wide spectrum of technical fields. In 2005, 2 MSc and 7 PhD students, together with 5 research assistants and 4 members of the technical staff of IST were involved in the study of theoretical problems related to air and marine robotics; a group of hired Research Engineers, among which 3 (Luis Sebastião, Manuel Rufino, and João Alves) are senior researchers, have been contributing very actively to the research and development program of DSORL by tackling more practically oriented problems in the fields of vehicle and system development, as well as operations at sea in the Azores and Sines, together with our scientific partners in the Associated Laboratory. Worth stressing is the involvement of the IMAR/DOP/UAzores in the definition of vehicle requisites, selection of scientific sensor suites, and logistic support (lab space, support vessels and manpower).

At a **theoretical** level, and following the main trend established over the past years, the main lines of research that are being pursued at the DSORL include the following:

T1. Linear and nonlinear systems theory.

T2. Robust Multiple-Model Adaptive Control (RMMAC): a new paradigm for robust control system design.

T3. Design of Navigation, Guidance, and Control (NGC) systems for autonomous vehicles.

T4. Motion Control of Single and Multiple Vehicles (air and marine robots) in the presence of communication constraints. Networked Control.

T5. Modelling, Parameter Estimation and Identification of Autonomous Underwater Vehicles (AUVs).

T6. Multiple Vehicle Mission Control techniques.

At a **practical** level, the emphasis is being placed on the following tasks in which the senior Research Assistants João Alves, Luis Sebastião, and Manuel Rufino have played leading roles:

P1. Design of AUVs and ASCs and on-board integration of scientific sensor suites and respective data acquisition / logging systems.

P2. Implementation of Navigation, Guidance, and Control (NGC) systems for autonomous vehicles.

P3. Hardware for coordinated navigation and motion control of multiple vehicles.

P4. Hardware for Multiple Vehicle Mission Control using distributed computer architectures.

P5. Tests and scientific missions with the robots developed.

The text that follows provides a brief description of some of the challenging topics for research and development listed above.

T1. Linear and nonlinear system theory

Study of theoretical tools for the **analysis and design of linear and nonlinear control / filtering systems**. The tools developed borrow from Linear Matrix Inequalities, Lyapunov stability theory, Backstepping techniques, ISS stability, and switching control. The applications centre around a vast range of problems that include, but are no limited to: a) path following and trajectory tracking for fully actuated and underactuated vehicles, b) speed, position, and attitude control, c) terrain tracking, and d) coordinated motion control of multiple autonomous platforms.

This line of research has received renewed impetus after Dr. António Aguiar joined the group in mid-2005. The main lines of research that he is currently pursuing can be summarized as follows:

Nonlinear control: Many control systems of practical importance are inherently nonlinear. A common practice for control system design is to linearize the system to be controlled around some equilibrium or operating point through small perturbation state approximations. The key assumption is that the range of operation is restricted to a small region around the equilibrium on which the linear model remains valid. As a consequence, adequate control is only guaranteed in a neighborhood of the selected operating points. Moreover, performance can suffer significantly when the required operating range is large, such as when controlling an autonomous vehicle that executes maneuvers that emphasize its nonlinearity and cross-couplings. Together with Prof. João Hespanha, from the University of California in Santa Barbara (UCLA), he derived in [142] several control algorithms for motion control of autonomous vehicles (land and marine vehicles, in two and three-dimensional space) and showed that nonlinear Lyapunov-based designs can overcome the limitations mentioned above. The important common features that these designs share are the fact that they explicitly exploit the physical structure of the systems under consideration instead of "fighting" it. Moreover, the work is focused on systems that are underactuated and are therefore especially challenging since standard tools used to control nonlinear systems - such as feedback linearization and integrator backstepping - are not directly applicable.

Switched and hybrid systems: The last few years have witnessed increasing interest in the subject of hybrid control, i.e., systems that combine continuous dynamics with discrete logic. Much of this interest has been motivated by applications in such diverse fields as car automation and aeronautics, real time software, communication protocols, transportation, traffic control, power distribution, robotics, and consumer electronics. Modeling, analysis, control and synthesis of such systems pose a considerable number of challenging problems making still an active research area. Recently, a new class of switched systems was introduced and mathematical tools were developed to analyze their stability and disturbance/noise attenuation properties. This work, done in cooperation with Prof. João Hespanha (UCLA) and Prof. António Pascoal, is summarized in [101]. In this work, a so-called seesaw control design methodology was proposed that yields closed-loop stability and robustness with respect to disturbance inputs. The methodology allowed for the design of a hybrid controller for an underactuated AUV that can operate in the presence of input disturbances and measurement noise. This was the culmination of a line of research on logic-based hybrid controllers to solve the stabilization problem for wheeled mobile robots and underactuated AUVs. A representative example of the work done is [142], where an adaptive supervisory control algorithm was proposed for a class of nonlinear systems in the presence of possibly large modeling parametric uncertainty. The class of hybrid adaptive algorithms based on switching and logic is interesting from a theoretical standpoint and can overcome limitations of adaptive control based solely on continuous tuning.

Performance limitations: An important step in control (and plant) design process is to assess how the plant model may limit the level of achievable performance, and to examine tradeoffs leading to realistic design goals. Because of its fundamental implications, this has been a topic of enduring interest, in both classical and recent control literature. Dr. António Aguiar´s interest in this topic is patent in [19], where in cooperation with Prof. João Hespanha and Prof. Petar Kokotovic he investigated the limits of performance in reference-tracking and path-following for non-minimum phase systems and highlighted an essential difference between them. It is well-known that in the reference-tracking, for non-minimum phase systems, there exists a fundamental performance limitation in terms of a lower bound on the L2-norm of the tracking error, even when the control effort is free. In [143] the authors showed that this is not the case for the less stringent path-following problem, where the control objective is to force the output to follow a geometric path without a timing law assigned to it. Furthermore, the same is true even when an additional desired speed assignment is imposed. This conceptual result is of great practical significance because the path-following formulation is convenient

for many applications and it shows that the classical approach of recasting path-following as a reference tracking problem may introduce performance limitations that are not inherent in the original problem. This prompted a renewed interest in design of path following controllers for non-minimum phase systems. Recently he derived, together with the co-authors of [143], analog limits of performance for a class of nonlinear systems [62], [142]. Following this trend, he organized a workshop on **"New Developments in Control Performance Limitation Research: A Tale in the Network Age"** for the 44th Conference on Decision and Control in Seville, (CDC'05), Spain, December 2005 (with Jie Chen, Rick Middleton, and Li Qiu).

Nonlinear observers: Over the last few decades there has been increasing interest in the design of observers for nonlinear systems. The extended Kalman filter is a widely used method for estimating the state of a nonlinear system. It is obtained by linearizing the nonlinear dynamics and the observation along the trajectory of the estimate. However, since it is only a local method, it often fails to converge. Several nonlinear observers using deterministic and stochastic approaches can be found in the literature: Lyapunov-like, Luenberger-like, high gain observers, sliding-mode observers, optimization-based, etc. In [144], Dr. António Aguiar and Prof. João Hespanha addressed the state estimation of systems with perspective outputs. In this work, minimum-energy estimators were constructed that produce an estimate of the state that is "most compatible" with the dynamics, in the sense that it requires the least amount of noise energy to explain the measured outputs. Under suitable observability assumptions, it was proved that the estimate converges globally asymptotically to the true value of the state in the absence of noise and disturbance. In the presence of noise, the estimate converges to a neighborhood of the true value of the state. Recently, this line of research led to the problem of estimating the state of a system with implicit outputs [77]. The problem was formulated in the so-called deterministic H - infinity filtering setting by computing the value of the state that minimizes the induced L2-gain from disturbances to estimation error, while remaining compatible with the past observations. The key advantage of these approaches compared with the extended Kalman filter is that the resulting observers are globally convergent under appropriate observability assumptions and can therefore be used to design output-feedback controllers.

T2. Robust Multiple-Model Adaptive Control (RMMAC): a new paradigm for robust control system design

Following previous research efforts, the work of doctoral student Sajjad FekriAsl, supervised by Profs. Michael Athans and António Pascoal, continued to focus on a novel Robust Multiple-Model Adaptive Control (RMMAC) architecture that explores an interesting and fruitful set of ideas set forth by Prof. Michael Athans. The new structure for robust control combines and integrates sophisticated identification methods and the state-of-the-art in robust control synthesis, using the mixed *Mu- methodology* for robust control of linear time-invariant systems subject to structured and unstructured uncertainty. The proposed RMMAC method does not seem to suffer from some of the *ad-hoc* design choices associated with the recent literature of using switching controllers using multiple-models. Moreover, RMMAC focuses upon *robust-stability and robust-performance*. The work has steadily progressed to a level where a methodology to design **robust adaptive controllers for multiple-input multiple-ouput plants with parametric uncertainty and unmodeled dynamics** is now available [147]. However, considerable work still remains to be done to fully extend the techniques developed so far for a large number of uncertain parameters. The work done was the subject of a Plenary Talk given by Prof. Michael Athans at the **16th IFAC World Congress**, Praha, Czech Republic, 2005.

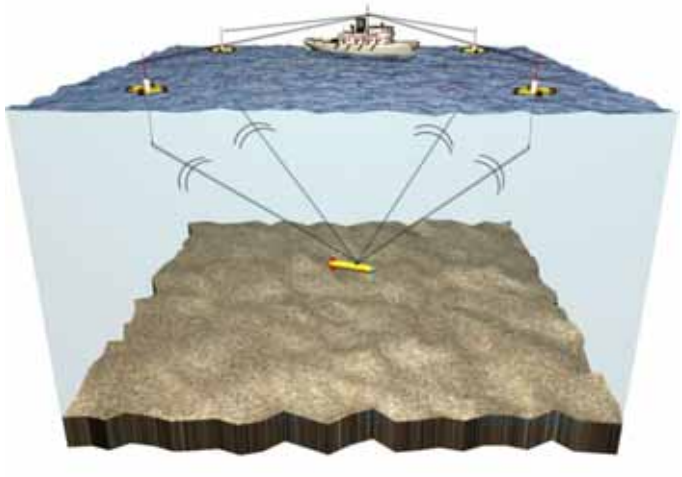
T3. Design of Navigation, Guidance, and Control (NGC) systems for autonomous vehicles.

This topic of research addresses the study of advanced systems for navigation, guidance, and control of autonomous vehicles using the techniques developed in T1. From a theoretical and even practical standpoint, some of the most challenging problems arise in the course of designing navigation and positioning systems for marine vehicles. *Navigation* refers to the problem of computing the linear position and attitude of an underwater platform and the respective linear and rotational rates. By *positioning* it is simply meant the problem of computing the position of an underwater platform. Recently there has also been great interest in the problem of *joint attitude and position estimation* (without immediate concern for the computation of the respective rates), based on so-called range / pseudo-range measurements. These three types of problems are being studied at ISR / IST. Special emphasis has been placed on the following key aspects:

i) Design and fabrication of a **moderate cost heading and attitude reference unit** (work carried out under the supervision of Profs Paulo Oliveira and Carlos Silvestre) that has proven quite valuable in terms of evaluating different types of accelerometers and mechanical / fiber optic gyros, as well as affording hands on experience

on the design and development of a unit that will equip future platforms, using hardware for real time distributed systems that is proprietary of ISR/IST. Work is also progressing on the development of a **inertial navigation system aided by GPS**, with applications to the control of aerial and surface vessels [77].

ii) Study and practical evaluation of **acoustics-based systems for underwater vehicle positioning** by resorting to a system that consists of four surface buoys equipped with DGPS receptors and submerged underwater hydrophones (so-called GIB system). Each of the buoys receives the acoustic impulses emitted periodically by a synchronized pinger installed on-board an underwater vehicle and records their times of arrival. The buoys communicate via radio with a central station (typically on-board a support vessel) where the position of the underwater vehicle is computed. Due to the fact that position estimates are only available at the central station, this system is naturally suited for tracking applications. The emphasis has been placed on the study of estimation algorithms that can cope with outliers, latency in the measurements, and multiple acoustic trajectories. The theoretical work is being done by PhD student Alex Peñas, under the supervision of Prof Paulo Oliveira and the co-supervision of Prof. António Pascoal. Practical work involved the modification of the commercially-available GIB system to have direct access to the raw data at the buoys, followed by algorithm implementation and tests at sea for performance evaluation [118], [146]. Future work will aim at the development of a proprietary system for underwater target positioning, including the necessary systems for the emission and detection of acoustic signals.



Acoustic Underwater Positioning System

iii) **Joint attitude and position estimation** systems based on range/pseudo-range measurements have received the attention of the engineering community, as an alternative to more complex, expensive, and sophisticated Inertial Navigation Systems. A good feature of such systems is that they are drift-less and insensible to magnetic disturbances. The study on the limits of performance of such systems and the development of methodologies to solve the estimation of joint position and attitude problems, borrowing from tools from Riemannian geometry, have been pursued by PhD student Alex Peñas, under the supervision of Prof Paulo Oliveira with the co-supervision of Prof. António Pascoal and in tight cooperation with Prof. João Xavier of the Signal Processing Group [135], [136].

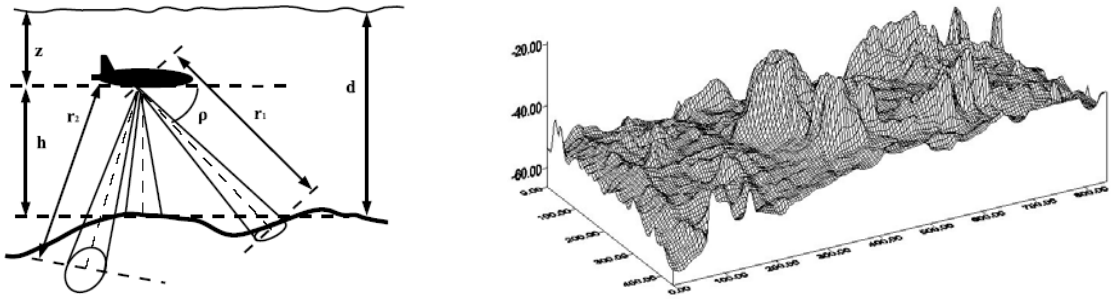
iii) Study and evaluation of the performance of **feature based navigation** algorithms. Navigation system design for the execution of long range missions with autonomous underwater vehicles (AUVs) in unstructured environments, resorting to a minimum of external sensors and yielding bounded error estimates, has been a major challenge in underwater robotics. The variations in the characteristics of the acoustic channel, coupled with noise and latency in sensor measurements, continuously degrade the accuracy of navigation systems along time, precluding their use in a number of interesting applications. External positioning systems have been proposed and successfully operated in the past and integrated in navigation systems for underwater applications. Unfortunately, all these systems provide only locally accurate measurements (a few square kilometres), take long time to deploy and are hard to calibrate, and constrain heavily the missions that

can be executed with AUVs. There simply is no remedy to this situation when the vehicles execute missions in open water, far away from the seabed and the sea surface, over long distances, with no clear landmarks "in sight".

The situation is completely different when a vehicle is asked to repeatedly survey an area where there are conspicuous landmarks (e.g. conspicuous terrain features, strong magnetic or gravimetric signatures, etc.). In this case, it is best to try and use this information to develop navigation system capable of correcting for the drift that is inherent to "inertial navigation-like" systems. This entails the use of **bathymetric, geomagnetic, and gravimetric data**.

To meet some of the above challenges, Prof. Paulo Oliveira continued his research effort towards the development of terrain based navigation systems (based on bathymetric maps) by resorting to the use of unsupervised optimal processing techniques of random signals, namely Principal Component Analysis (PCA) [52]. He also pursued the development of Multiple Model Adaptive Estimator (MMAE) Terrain Reference Navigation Systems for underwater vehicles using Eigen Analysis [62], [99]. The performance of the algorithms derived was studied for a large set of terrains carefully chosen, providing bounds on the expected stochastic performance for the problem at hand, resorting to a series of Monte Carlo experiments. The results obtained pave the way to the use of the proposed sensor in real positioning applications for underwater robotics.

In a parallel effort, doctoral student Francisco Teixeira (under the supervision of Prof. António Pascoal) continued his research on the subject of underwater vehicle navigation using bathymetric data. In his work, he derived a new type of particle filter that effectively merges information provided by a Doppler log, an attitude unit, and a set of echosounders. In the course of his work, an efficient way was found to model the type of information provided by an echosounder as a function of the terrain (local slope, roughness, etc.). Stimulating simulation results obtained with a digital terrain map of the D. João de Castro seamount show the potential of the filter to the development of terrain based navigation systems [97], [119]. He also evaluated the performance achieved by exploiting the use of multiple echo-sounders. Recently, he started to address the problem of AUV navigation using geomagnetic data [137]. Interestingly enough, an extensive literature survey reveals that only a few papers on this issue have appeared in the literature. The subject is challenging both from a theoretical and practical standpoint: theoretically, it requires that tools from Geomagnetism be used (namely, upward and downward continuation of potential geomagnetic fields); the practical issues to be resolved revolve around the need to estimate and cancel out the influence of the magnetic field generated by the platform on which the measuring device (magnetometer) is installed. Contacts have been established with Dr. Dana Yoeger of the Woods Hole Oceanographic Institution, USA to share geo-referenced magnetic data acquired with the Autonomous Benthic Explorer (ABE) AUV over the D. Juan de Fuca Ridge.



AUV terrain-based navigation; Bathymetric map of the D. João de Castro seamount (Azores, Portugal)

T4. Motion Control of single and multiple vehicles (air and marine robots) in the presence of communication constraints. Networked Control.

At ISR/IST there has been considerable research activity on the problems of motion control of single and multiples autonomous vehicles. The key problems under study are summarized below.

Motion control of single autonomous vehicles: The ever increasing sophistication of autonomous vehicles is steadily paving the way for the execution of complex missions without direct supervision of human operators. A key enabling element for the execution of such missions is the availability of advance systems for motion control of autonomous vehicles. The past few decades have witnessed considerable interest in this area. The problems of motion control addressed in the literature can be roughly classified into three groups: point stabilization, where the goal is to stabilize a vehicle at a given target point with a desired orientation; trajectory tracking, where the vehicle is required to track a time parameterized reference, and path following, where the vehicle is required to converge to and follow a desired geometric path, without a timing law assigned to it. For underactuated autonomous vehicles, i.e., systems with a smaller number of control inputs than the number of independent generalized coordinates, motion control is still an active research topic. The study of these systems is motivated by the fact that it is usually costly and often impractical (due to weight, reliability, complexity, and efficiency considerations) to fully actuate autonomous vehicles. Typical examples of underactuated systems include robot manipulators, wheeled robots, walking robots, spacecraft, aircraft, helicopters, missiles, surface vessels, and underwater vehicles.

Over the past years, Dr. António Aguiar - in cooperation with Prof. João Hespanha –has been researching the problem of motion control of underactuated autonomous vehicles and nonholonomic systems. Recently, in [142] they proposed a solution to the trajectory-tracking and path-following problem for underactuated autonomous vehicles in the presence of possibly large modeling parametric uncertainty. For a general class of vehicles moving in either two or three-dimensional space, they demonstrated how adaptive switching supervisory control can be combined with a nonlinear Lyapunov-based tracking control law to design a hybrid controller that yields global boundedness and convergence of the position tracking error to a small neighborhood, and robustness to parametric modeling uncertainty. These results are illustrated in the context of two vehicle control applications: a hovercraft (moving on a planar surface) and an underwater vehicle (moving in three-dimensional space). Collaborative work of Dr. António Aguiar, Prof. João Hespanha, and Prof. António Pascoal, has also led to the development of a new methodology for the design of switching control system for motion control of underactuated vehicles [57]. A monograph on nonlinear motion control of underactuated autonomous vehicles (co-authored by Dr. António Aguiar, Prof. João Hespanha, and Prof. António Pascoal) that summarizes the work done has been finalized and accepted for publication. The monograph addresses the problems of point stabilization, trajectory tracking, and path following, and includes examples of applications to marine vehicles and a hovercraft.

Visual servo control. On a complementary vein, Dr. António Aguiar and Prof. João Hespanha have been also doing research on control systems that utilize machine vision as a feedback sensor, also known as visual-servo control. This area poses considerable challenges and opportunities in control engineering and requires substantial research work on system analysis and design. Over the last decade, visual servoing applications have increased dramatically. The use of a vision system in closed-loop control schemes increases the flexibility and accuracy of robotic systems. Depending on the setup at hand, vision-based control can be used to perform many different tasks such as navigation, manipulation, tracking, etc. However, the use of vision systems introduces significant difficulties because of its nonlinearity and its extreme sensitivity to the environment. The environment is made by objects with complex geometry (shape), complex photometry (appearance) and complex dynamics (motion, deformation). In [144], both authors explored the use of vision to solve the estimation of position and orientation of a mobile robot that uses a monocular charged-coupled-device (CCD) camera mounted onboard to observe the apparent motion of stationary points. The estimators proposed can deal directly with the usual problems associated with vision systems such as noise, latency and intermittency of observations. They have also developed and implemented a real-time system to control a mobile robot to park at a desired target using only vision [144]. More recently, in [77], they have derived an observer to estimate the position and attitude of an autonomous vehicle combining the measurements from an inertial measurement unit (IMU) and from a monocular CCD camera attached to the vehicle. Future work will address similar problems in the marine world.

Path Following for Air Vehicles. Under the guidance of Prof. Carlos Silvestre, doctoral student Rita Cunha, has been addressing the problem of steering an autonomous helicopter along a predefined 3-D path, while tracking a desired velocity profile (path-following). The solution to this problem relies on the definition of a path-dependent error space to express the dynamic model of the vehicle, which is expected to exhibit a high degree of directional accuracy. The methodology adopts a polytopic Linear Parameter Varying (LPV) representation with piecewise affine dependence on the parameters to accurately model the error dynamics over a wide flight-envelope. The synthesis problem is stated as a discrete-time H_2 control problem for LPV

systems and solved using Linear Matrix Inequalities (LMIs). To achieve better path-following performance, a preview control technique is adopted, which amounts to introducing a feedforward term driven by future path disturbances. Implementation of the nonlinear controller is addressed within the framework of gain-scheduling control theory using the so-called D-methodology. The effectiveness of the proposed controller has so far been assessed in simulation using the full nonlinear model of a small-scale helicopter [61] .

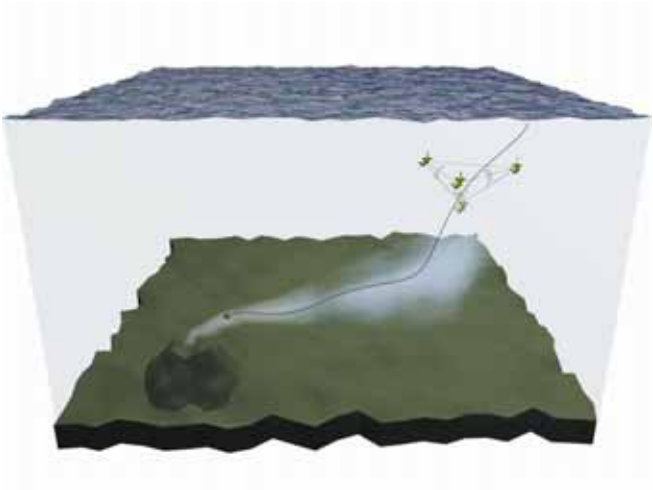
Terrain Contour Tracking for AUVs and Air Vehicles. Supervised by Prof. Carlos Silvestre, doctoral student Rita Cunha and Research Associate Nuno Paulino have addressed the problem of terrain tracking for both autonomous underwater vehicles by taking into account the terrain characteristics ahead of the vehicles, as measured by dedicated sensors (e.g. two forward looking echosounders in the case of AUVs) [76], [122], [126], [144]. The methodology adopted to solve the this problem amounts to posing it as a discrete time path following control problem where a conveniently defined error state space model of the plant is augmented with altitude (above the terrain) preview data. A piecewise affine parameter-dependent model representation is used to accurately describe the vehicle linearized error dynamics for a pre-defined set of operating regions. For each region, the synthesis problem is stated as a state feedback H_2 control problem for affine parameter-dependent systems and solved using Linear Matrix Inequalities (LMIs). The resulting nonlinear controller is implemented in the scope of gain-scheduled control theory using so-called D-methodology. Future work will aim at applying the results obtained to the control of the INFANTE AUV and an autonomous helicopter. nonlinear model paving the way to the implementation and evaluation in tests at sea.

Coordinated/cooperative control of a group of autonomous vehicles: The past decade has witnessed the emergence of autonomous behaviours in single mobile systems, with applications to the safe operation of ground, air, and marine vehicles in the presence of changing and unknown environmental conditions The experience thus acquired is now steadily being brought to bear on the solutions to far more complex, albeit similar problems, that arise when multiple systems must work together. This shift of attention was brought about by the introduction of the concept of *multiple autonomous vehicles* performing missions cooperatively as an attractive alternative to the traditional single vehicle paradigm. The multiple vehicle approach offers several advantages such as increased efficiency, performance, reconfigurability and robustness, and new emerging capabilities. Furthermore, technological advances in communications and in miniaturization of electro-mechanical systems are making possible and relatively inexpensive the deployment of groups of networked vehicles in a number of environments. Some of the potential applications include tasks that involve searching and surveying as well as exploration and mapping in harsh environments. A cooperative network of autonomous vehicles can also adapt the behavior / configuration of the network in response to the measured environment in order to improve performance and optimize the detection and measurement of fields and features of particular interest. Furthermore, each vehicle could carry only a single sensor (per environmental variable of interest) making them less complex, and consequently increasing its reliability. Notice also that sensors may require considerable power or space and these are typically at a premium. On the other hand, the coordination of autonomous vehicles involves the design of distributed control laws with limited and disrupted communication, uncertainty and imperfect or partial measurements. This is particular significant for the case of underwater vehicles. These constraints together with safety, robustness and performance are critical properties that must be directly taken into account in the design of the control algorithms.

The above problems are extremely challenging, both from a theoretical and practical standpoint, and many of the simplest ones lie at the boundary of current tools and understanding. An aspect that is likely to be particularly important is the integration of controls, communications, computing, and networks. Today, dynamic system theory provides a rich methodology and a supporting set of mathematical principles and tools for analysis and design of navigation, guidance, and control systems for single autonomous vehicles. However, in this new context, many traditional approaches may no longer work and therefore it is imperative to develop new paradigms for designing robust, high performance multi-vehicle systems. To model the integration of physical continuous systems, event-based protocols, and real-time software, a framework of choice is to use *hybrid* systems. From the point of view of systems implementation, the solution is clearly to explore fast paced developments in the area of embedded systems.

At ISR/IST, there has been considerable research activity in this vibrant area towards the development of algorithms for coordinated motion control of marine vehicles. The interest of the group in this area goes back to approximately 10 years ago, when the so-called ASIMOV concept was first proposed in the scope of a European project coordinated by IST. The concept involves the concerted operation of an autonomous underwater vehicle (AUV) and an autonomous surface craft (ASC). In this scenario, an autonomous surface craft (ASC) is required to follow a desired path accurately while an autonomous underwater vehicle (AUV) operating at a fixed depth is required to follow exactly the same horizontal path (shifted in the vertical coordinate), while tracking the ASC motion along that path. See the joint figure.

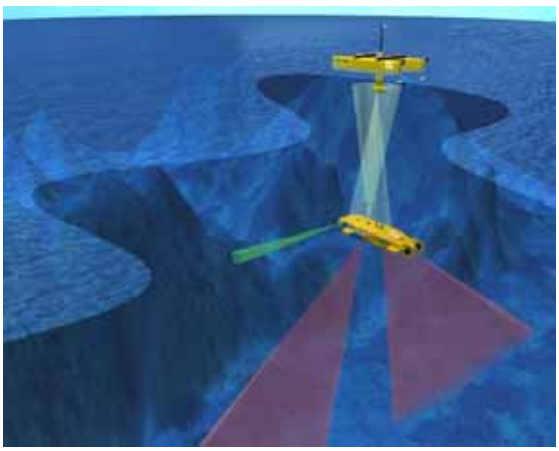
Combined autonomous surface craft / autonomous underwater vehicle control.



The quest for hydrothermal vents using multiple AUVs equipped with methane sensors.

In this example, the AUV serves as a mobile sensor suite to acquire scientific data, while the ASC plays the role of a fast communication relay between the AUV and a support ship. Thus, the ASC effectively explores the fact that high data rate underwater communications can best be achieved if the emitter and the receiver are aligned along the same vertical line. Notice how both vehicles are required to follow exactly the same type of path (shifted in the vertical), which is imposed by the scientific missions at hand. Other challenging scenarios can of course be envisioned, namely using a fleet of underwater vehicles to detect the source of a hydrothermal vent by computing on-line and following the gradient of methane concentration.

The research done at IST/ISR in this area departs from mainstream work in that it focused on **Coordinated Path Following**: a set of vehicles is required to converge to and follow pre-assigned paths and, once on the paths, synchronize their motion so as to reach a desired formation pattern. Related work is being pursued by the group of Prof. Thor Fossen and Prof. Kristin Pettersen at the NTNU, Norway. This motivated the work of Ph.D. student Reza Ghabcheloo supervised by Profs. António Pascoal and Carlos Silvestre, in collaboration



with Prof. Isaac Kaminer of the Naval Postgraduate School, Monterey, CA, USA. He has addressed the problem of steering a fleet of mobile robots along a set of given spatial paths, while keeping a desired inter-vehicle formation pattern. This problem arises for example when multiple vehicles are required to scan a given area in cooperation. In a possible mission scenario, one of the vehicles acts a leader and follows a path accurately, while the other vehicles follow paths that are naturally determined by the formation pattern imposed. However, other inter-vehicle coordination schemes are allowed. The solution proposed addresses explicitly the dynamics of the cooperating vehicles and the constraints imposed by the topology of the inter-vehicle communications network. Lyapunov-based techniques and graph theory are brought together to yield a decentralized control structure where the information exchanged among the robots is kept at a minimum. With the set-up proposed, path following (in space) and inter-vehicle coordination (in time) are essentially decoupled. Path following for each vehicle amounts to reducing a conveniently defined error variable to zero. Vehicle coordination is achieved by adjusting the speed of each of the vehicles along its path according to information on the positions and speeds of a subset of the other vehicles, as determined by the communications topology adopted. *No other information is exchanged among the robots.* In his work he obtained a formal proof of asymptotic stability (convergence and stability in the sense of Lyapunov) of the coordinated path following control scheme both for land robots and fully actuated underwater vehicles [57], [98], [100], [132], [133], [145], [148]. More recently, by exploiting fruitful collaboration links with Dr. António Aguiar, he has been working on the extension of the above results to a very general class of vehicles (thus allowing for the consideration of underactuated marine vehicles) while addressing explicitly the problems that arise due to communication failures and communication delays. The mathematical machinery adopted borrows from the theory of systems with Brief Instabilities. The results obtained so far hold promise to the development of formal tools to study stability and performance of the coordinated behaviour of a fleet of vehicles.

Networked control. In many complex control systems, such as manufacturing plants, autonomous vehicles, aircraft, and spacecraft, communication networks are employed to exchange information and control signals between spatially distributed controllers, sensors and actuators. These control architectures, called networked control systems (NCSs), are being adopted in many application areas for a number of reasons including their low cost, reduced weight, and power requirements, simple installation and maintenance, and higher reliability. However, using a network presents some new challenges because the network itself is a dynamical system that exhibits characteristics that traditionally have not been taken into account in control system design. These special characteristics include quantization and time-delays and are a consequence of the fact that practical channels have only a limited bandwidth. Thus, a networked controller needs to be designed to take into account the communication channel. In [141], Dr. António Aguiar and Prof. João Hespanha addressed these problems from the point of view of the observer designer. They investigated the problem of estimating the state of continuous-time systems with perspective outputs when the measured outputs are transmitted through a network. They considered measurements that arrive at discrete-time instants, are time-delayed, noisy, and may not be complete. An observer was designed that guarantees that the estimation error satisfies an input-to-state stability-like condition with respect to noise and disturbances. These results are expected to play a relevant role in the development of advanced systems for coordinated motion control (examined above).

T5. Modeling, Parameter Estimation and Identification of AUVs (Autonomous Underwater Vehicles).

In recent years, a new line of research arose out of the interaction with Prof. Ettore Barros from the Univ. São Paulo, Brasil, who spent his sabbatical license at ISR/IST in 2003-2004. His research program addressed the general problem of autonomous *underwater vehicle (AUV) modelling and parameter estimation* as a means to predict the expected dynamic performance of AUVs and thus guide their design phase well before they can be tested at sea. This will shorten the time of vehicle design and development and reduce drastically the costs associated with intensive hydrodynamic tank tests.

Analytical and Semi-Empirical Methods for the estimation of AUV hydrodynamic derivatives were studied and applied to the estimation of the hydrodynamic derivatives of the MAYA AUV, an autonomous vehicle that is being developed under a joint Indian-Portuguese project. The parameter estimates were used to predict the behaviour of the vehicle in the vertical plane and horizontal planes and to assess the impact of stern plane size on its expected performance. The model obtained was instrumental in developing controllers for the AUV. Their performance will be assessed during missions with the real vehicle in India, in early 2006.

In the course of this work, cooperation agreements have been established with the Department of Engineering Cybernetics, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, and the National Institute of Oceanography (NIO), Dona Paula, Goa, India. The NTNU has the facilities required to run hydrodynamics tank tests, while NIO has agreed to run AUV CFD analysis using parallel computing facilities available in India. A cooperation programme has also been established with Prof. Falcão Campos (Dept. Mechanical Engineering of IST), an expert in hydrodynamics and propeller theory, who is interested in estimating some of the key hydrodynamic parameters of the MAYA AUV with a view to designing a high-efficiency propeller for increased vehicle autonomy. This work is being coordinated by Research Assistant Luis Sebastião.

T6. Multiple Vehicle Mission Control techniques

Over the past eight years, ISR/IST has steadily been developing methodologies for **Mission Control** which, after implementation using dedicated hardware and software architectures, can afford end-users the tools to seamlessly programming and execute missions with robotic vehicles in a completely autonomous mode. The main bulk of the work done so far led to CORAL, a Petri Net software application that is proprietary of ISR/IST and allows for mission programming and execution in real-time. Central to the development of CORAL was the concept of Vehicle Primitive (VP), a parameterized basic "action" of the vehicle being controlled that can be offered as a "resource" to the vehicle Mission Control System (MCS). Examples of Vehicle Primitives include Heading Command Tracking, Depth Command Tracking, and Terrain Following, to name but a few.

In a great number of mission scenarios involving cooperation among multiple vehicles one must extend the tools available for single vehicles to ensure the coordinated operation of a complete fleet. Thus, one is confronted with the need to develop a set of Multi-Vehicle Primitives (MVP) that can be offered as "resources" to the Coordination Mission Control System (CMCS) in charge of the complete multi-vehicle operation. Examples include the Multi-Vehicle Primitives aimed at implementing the following:

1. *Combined autonomous surface vehicle / autonomous underwater vehicle control*. In this scenario, an autonomous surface craft (ASV) is required to follow a desired path accurately while an autonomous underwater vehicle (AUV) operating at a fixed depth is required to follow exactly the same horizontal path (shifted in the vertical coordinate), while tracking the ASV motion along that path. In this example the AUV serves as a mobile sensor suite to acquire scientific data, while the ASC plays the role of a fast communication relay between the AUV and a support ship. Notice how both vehicles are required to follow exactly the same type of path, which is imposed by the scientific missions at hand. Similar comments apply to the combined operation of an ASV to which a remotely operated vehicle is connected through an umbilical
2. *Cooperative autonomous underwater vehicle control: video acquisition*. This scenario occurs when an underwater vehicle carries a strong light source and illuminates the scenery around a second underwater vehicle that must follow a pre-determined path and acquire video images for scientific purposes.
3. *Cooperative autonomous underwater vehicle control*: *fast acoustic coverage of the seabed.* In this important case, two vehicles are required to fly above the seabed at the same or different depths, along parallel paths, and map the seabed using two copies of the same suite of acoustic sensors (e.g. sidescan, mechanically scanned pencil beam, and subbottom profiler). By requesting the two vehicles to traverse identical paths so as to make the acoustic beam coverage overlap on the seabed, large areas can be covered in a fast manner.

Clearly, these Multi-Vehicle Primitives are essentially time-driven (in opposition to event-driven) and involve dynamics that typically occur at faster rates than those of the events associated with the "higher level" Coordination Mission Control System. For example, a set of vehicles may be asked to execute a given MVP by the CMCS. However, as a reaction to the conditions of the environment, the CMCS may wish at some point to invoke a new MPV. It is up to the new MVP supervisor to trigger the set of actions aimed at transitioning between Primitives in a *safe manner*. In this context, one is led naturally to the need of defining a basic number of MVPs. Among these, the following have been the subject of current intensive research at ISR/IST: path following, trajectory tracking, combined path following / trajectory tracking, and coordinated path following, as detailed in Section T4 above.

The apparent simplicity of the above examples of Primitives hides the complexity of the plethora of problems that must be solved to fully implement them. In fact, the execution of these Primitives requires that a number of Navigation, Guidance, and Control Systems be in place (on each vehicle) and that the algorithms for coordinated navigation and control yield adequate performance *in the face of environment disturbances and communication failures*. The importance of the latter can hardly be overemphasized, given the extremely hard constraints imposed by the marine environment and the sheer lack of high bandwidth, reliable communication links underwater.

With a view towards developing practical solutions for the implementation of Multi-Vehicle Primitives, we have been exploring the use of Petri Nets and developing *hardware architectures* for distributed real-time control of ocean robotic vehicles. Here, we are tacitly assuming that the "rates" of the time-driven and event-driven systems are drastically different. The work builds on previous development efforts that led to CORAL and on the work of former MSc student Rudolfo Oliveira (under the supervision of Prof. Carlos Silvestre) who solidified the extension of CORAL to deal with multiple vehicle operation. In 2005, the focus was on the completion of a real-time distributed architecture that will give support to the implementation of a Coordinated Mission Control System for the vehicles that are property of ISR/IST. This work led to the MSc thesis of Research Assistant João Alves on Real Time Architectures for Autonomous Vehicles [124].

2.2.7 AERONAUTICS (AERO)

The research activity of the aeronautics group includes several topics in the domain of the aeronautical and space science:

- **Aeroacoustics:** studies of the acoustics of moving and inhomogeneous media, including helicopter rotor noise, noise propagation near airports, noise shielding by aircraft structures, noise of jet engines;

- **Flight dynamics**: stability and control of new aircraft configurations, like flying wings and V-tails, and associated aspects like handling qualities and manouver points, cruise trim with minimum drag, maximization of control effectiveness;

- **Space physics:** physics of space plasmas, including problems of solar-terrestrial physics, such as mass and energy transport in the solar atmosphere and wind, including the role of hydromagnetic waves; orbital mechanics and the physics of atmosphere re-entry;

- **Modelling methods:** mathematical and physics methods, including the solution of boundary and initial value problems, and of partial and ordinary differential equations with singularities, using special functions and the method of fractional calculus;

- **Flight testing:** development of flight testing capabilities and performance of flight tests in several domains, namely operational evaluation and use of the EGNOS system and POAF fleet fatigue evaluation.

3. RESEARCH ACTIVITIES

3.1 RESEARCH PROJECTS (33)

This section contains a brief description of the R&D projects in progress at ISR (Lisbon), IST and University of Algarve during 2005, under the supervision of ISR members. The subsections define the main areas of intervention where the projects are being developed. The projects resulting from contracts celebrated with ISR and managed by this private research institution are identified by (*) on the title; all the remaining projects refer to contracts celebrated and managed by IST and University of Algarve.

3.1.1 UNDERWATER AND OCEAN ROBOTICS

Project name: **RUMOS -** ROBOTIC UNDERWATER VEHICLES AND MARINE ANIMALS TRACKING SYSTEMS

Project leader within ISR: Prof. Paulo Oliveira (ISR / IST)

Project description: The main purpose of the project is the development of a set of devices and methodologies for precise estimation of trajectories of underwater robotic vehicles (autonomous and remotely operated) and marine animals.
In order to overcome the problems that occur due to the highly noise environment and the presence of a multitude of disturbances a number of efforts must be set forth to overcome the problem at hand.
The topics include:
i) Mission scenario characterization;
ii) Development of high gain power amplifiers for acoustic wave generation;
iii) Development of very-low noise acoustic data acquisition systems;
iv) Study and development of accurate navigation algorithms for sensor fusion;
v) Development of post-processing techniques for very precise trajectories estimation;
vi) Accurate and real-time monitoring of 3D trajectories in selected coastal and oceanic fish species.

Research Areas: Underwater Positioning Systems, Tracking Systems, Sensor Fusion, Behavior and Ecology of fishes
Laboratories: Dynamical Systems and Ocean Robotics Lab (DSORL)
External Partners: IMAR / Department of Oceanography and Fisheries, Univ. Azores
Initiated: December 2005
Conclusion: December 2008
Classification: POCI / MAR / 55609 / 2004
Documents produced in 2005:

♦

Project name: **MAYASub** – DEVELOPMENT OF A SMALL AUV FOR SCIENTIFIC AND COMMERCIAL APPLICATIONS

Project leader within ISR: Prof. António Pascoal (ISR IST)

Project Coordinator: Prof. António Pascoal (ISR / IST)

Project description: The key objective of the project is to develop and demonstrate the performance of a small, modular, autonomous underwater vehicle (AUV) for scientific and commercial applications. Envisioned missions include geological and oceanographic surveys, marine biology studies, marine habitat mapping for environmental management, inspection of harbours and estuaries, and marine pollution assessment, to name but a few. Vehicle miniaturization will be achieved by resorting to small embedded processors, miniaturized sensors, and high performance actuators. Modularity will allow for easy vehicle reconfiguration according to different mission

scenarios. Reduced weight will make it possible to launch and retrieve the vehicle by resorting to small ships of opportunity. The ultimate goal of the project is the development (by a Portuguese-Indian consortium) of two copies of a highly reliable mobile platform that will act as a natural extension of its support ship, effectively allowing an operator to probe the surrounding 3D environment from the comfort of his/her lab at sea.

In 2005 the design of the systems for navigation, guidance, and control of the MAYA_type AUU was consolidated. The first tests with the control systems for the vertical and horizontal plane will take place in Goa, India in February-March 2006. At a mechanical/electrical level, the work focused on the study of a safety device for weight release upon vehicle failure detection as well as on the control plane (fins) arrangement for increased maneuvering performance.

The MAYA AUV – Mechanical Design of the NIO, India

Research Areas: Marine Vehicle Design, Hydrodynamic Parameter Estimation and Identification, Navigation, Guidance, and Control, Acoustic Marine Sensors, Underwater Positioning and Communications
Laboratories: Dynamical Systems and Ocean Robotics Lab (DSORL), VISLAB
External Partners: RINAVE (PT), IMAR/DOP/Univ. Azores (PT), National Institute of Oceanography (NIO), Dona Paula, Goa, India, System Technologies (ST), Ulverston, UK
Initiated: January 2003
Expected conclusion: July 2007
Classification: AdI (Agência de Inovação)
Documents produced in 2005: [52], [59], [62], [97], [98], [99], [118], [119], [124], [132], [135], [136], [146], [149]

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Project name: EXOCET/D – Extreme ecosystem studies in thr deep Ocean: Technological Development

Project leader within ISR: Prof. António Pascoal (ISR/IST)

Project Coordinator: Dr. Pierre Marie Sarradin, IFREMER (FR)

Project description: The aim of this project is the technological development of a specific instrumentation suite allowing the study of natural or accidentally perturbed ecosystems found in the deep ocean. These ecosystems are related to the emission of reduced fluids (cold seeps, hydrothermal vents), peculiar

topographic structures (seamounts, deep corals), massive organic inputs (sunken woods) or to unpredictable events (pollution, earthquakes). Beside their insularity in the abyssal plain, the targeted ecosystems are characterised by patchy faunal distributions, unusual biological productivity, steep chemical and/or physical gradients, high perturbation levels and strong organism/habitat interactions at infra-metric scales. Their reduced size and unique biological composition and functioning make them difficult to study with conventional instrumentations deployed from surface vessels. Their study requires the use of submersibles able to work at reduced scales on the seafloor as well as the development of autonomous instruments for long-term monitoring (seafloor observatories).

The general objective of the EXOCET/D is to develop, implement and test specific instruments aimed at exploring, describing and quantifying biodiversity in deep-sea fragmented habitats and to identify links between community structure and environmental dynamics. Inboard experimental devices will complement the approach, enabling experiments on species physiology. The EXOCET/D working fields include: video and acoustic imagery; *in situ* analysis of habitat chemical and physical components; quantitative sampling of organisms; *in vivo* experiments; 4D integration of multidisciplinary data; implementation on European deep-submersibles as well as validation during demonstration actions. The *work of IST/ISR focuses on the development of the acoustic systems that are required to acquire acoustic backscattering data obtained with a mechanical scanning pencil beam sonar.* The data will be used for remote marine habitat classification. The final system developed by IST/ISR will be installed on-board the VICTOR ROV, property of IFREMER, for inspection of deep water hydrothermal vent communities during a cruise that will take place in August 2006. The figures below illustrate part of the activity developed in the course of the project.

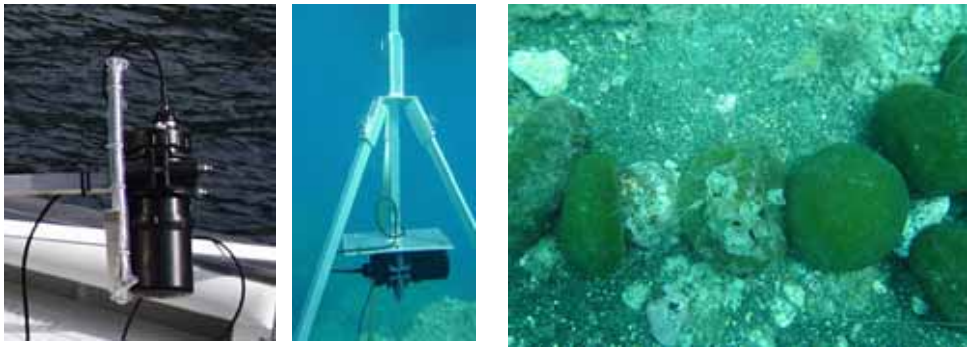

Fig. B.

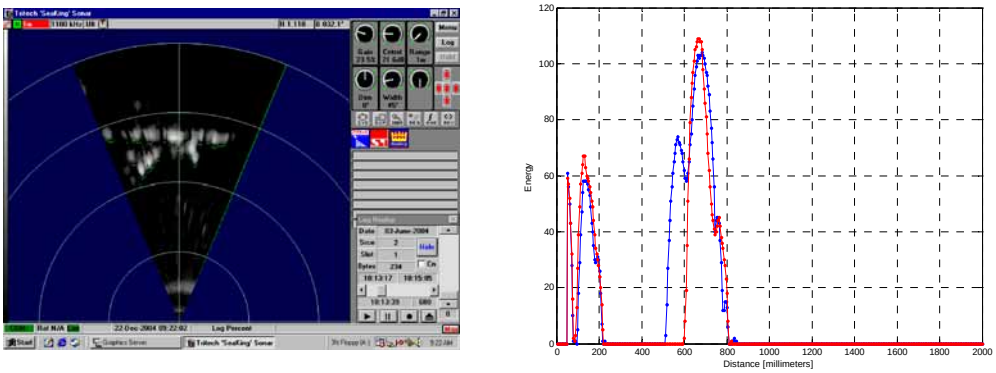

Fig. C

Figure B. Left: view of mechanical scanning sonar: Middle: the sonar installed underwater; Right: organisms (algae) to be identified remotely.
Figure C. Left: sonar image obtained underwater. The “image” of the organisms on the seafloor is visible; Right: data acquired showing the backscatter data. The second sequence of impulses represents “true” backscatter.

Research Areas: Acoustic data acquisition and processing, real time-systems, navigation
Laboratories: DSORLab
External Partners: IFREMER (FR), IMAR/DOP/Univ Azores (PT), AWI (GER), UPMC (FR), CNRS (FR), Cardiff University (UK), Heriot-Watt Univ. (UK), U. Algarve (PT), Univ. Bremen (GER), SeeByte (UK), Systea (IT), Capsum Gmbh (GER), and KC-Denmark (DK)
Initiated: January 1, 2004
Expected conclusion: December 31, 2006
Classification: EC funded project, 6th Framework Programme
Documents produced in 2005: [123], [125], [127]

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Project name: **MEDIRES –** METODOLOGIAS DE DIAGNÓSTICO E INSPECÇÃO ROBOTIZADA DE ESTRUTURAS SUBMERSAS (Methodologies for Surveying and Diagnosis of Semi-submerged Structures)

Project leader within ISR: Prof. Carlos Silvestre (ISR/IST)

Project Coordinator: Dr. João Alfredo Santos (LNEC)

Project description: The cost of a rubble-mound breakwater, its expected behaviour, as well as the consequences of its failure, do justify the existence of a monitoring programme which helps in the decision making process relative to the timing of the maintenance, or even repair, works. However, the continuous monitoring of the status of any given breakwater stretch is not yet feasible. That is why the most common procedure consists of the periodic inspection of these structures. The goals of the MEDIRES project are twofold:

I- To use the latest technological breakthroughs in positioning, navigation and control of surface autonomous vehicles to develop new techniques for accurate and efficient inspection of the geometry of semi-submerged structures with application to rubble mound breakwaters. This activity will end up with the development of a tool, named IRIS, for high accuracy surveying of both the above water and submerged parts of the armour layer of rubble-mound breakwaters (or semi-submerged structures, in general). This tool that can be used in autonomous mode or equip an Autonomous Surface Craft to produce tri- dimensional surveys with the spatial regularity required to this kind of structures;
II- To condense the large volume of data from the periodic inspections into a small set of parameters that enables the characterization of the structure's status and evolution. The definition of the parameters thresholds, needed for the structure's diagnosis, will be based on LNEC's past experience as well as on results from scale model tests.

The tool (IRIS) will be designed to equip the autonomous catamaran DELFIMx. Within the framework of this project, accurate path following control and navigation systems will be developed in order to guarantee the repeatability of the maneuvers so as to ensure the quality of the survey data sets obtained. Nevertheless, the IRIS can be used in standalone mode without the autonomous vehicle.

The autonomous catamaran, named DELFIMx, is capable of following pre-assigned trajectories with a high level of accuracy. It is equipped with two back electrical thrusters and can travel at a maximum speed of 5 knots. In order to determine its position and speed it uses differential GPS and an attitude reference unit. Using the information available from its motion sensor suite the catamaran DELFIMx computes its actual position and orientation and respective velocities.A real time computer network developed at the Institute for Systems and Robotics is used in the autonomous vehicle DELFIMx. This network was specially designed for multi-vehicle robotic applications, uses wireless modems, and implements TDMA (Time Division Multiple Access). The network will effectively allow an operator to supervise the IRIS tool during the survey. Figure 2 depicts the concept of the Catamaran DELFIMx equipped with the IRIS, during a typical breakwater survey. The figure shows how the tool is placed in the Catamaran and illustrates how the 2D laser range finder and the sonar profiler can be used in a breakwater survey mission.

The inspection techniques to develop within the framework of this project will be tested in Sines' West breakwater and in the breakwater of the Avilés port (in Astúrias, Spain). Several surveys will be conducted during the project, to identify and tune the algorithms and tools for online data set acquisition and off-line processing.

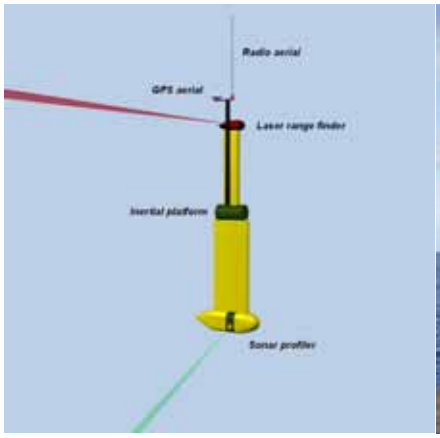


Figure 1 Figure 2

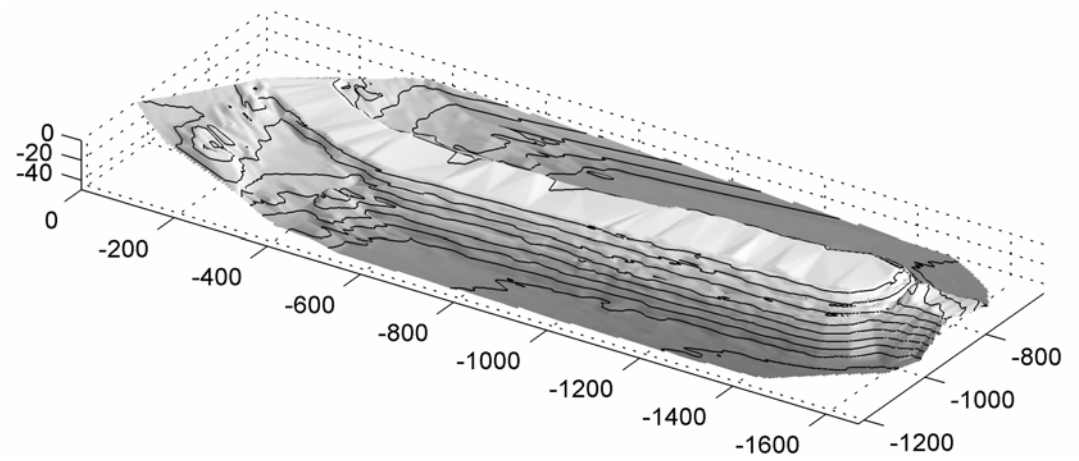
So far, two surveys of the armour layer of Sines west breakwater were carried out with IRIS. The first one took place on June 2003, while the second took place in June 2004. In the 2003 survey, the first time ever IRIS was used, it become obvious that at least two not so small details had been overlooked that far.The first one was related to the measurement of the Earth magnetic field that was fundamental to find the IRIS' heading. In order to get heavier Antifer cubes at the head of the breakwater, hematite, an iron ore, was included in the concrete aggregates. That is the cause for the darkish area at the breakwater head in the pictures of Sines west breakwater. This means that the heading measurements from the electronic compass were disturbed by the structure. This problem lead to the development of the procedure to estimate the IRIS heading that is now implemented: two GPS receivers, one at the fore and another at the aft of the support vessel give the vessel's heading and IRIS heading.

a)  b) 

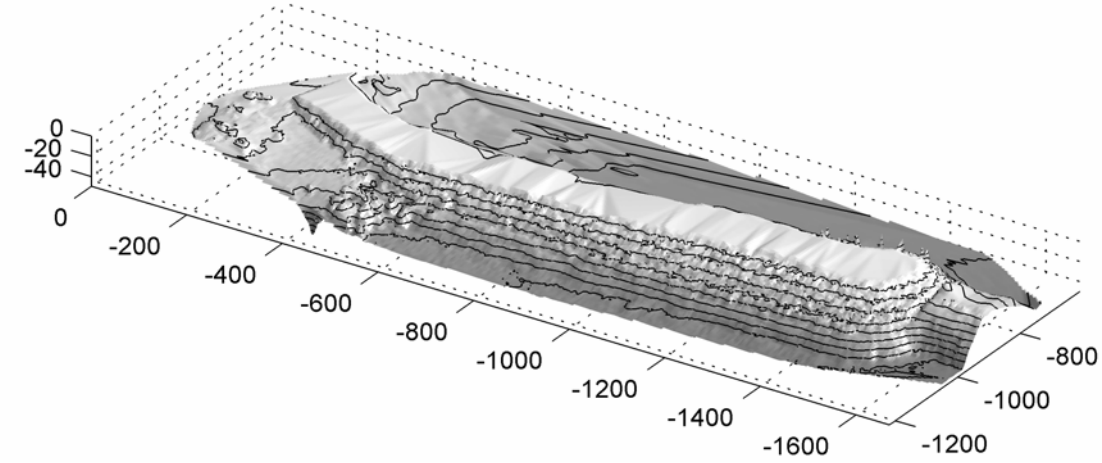
Figure 3. The IRIS high accuracy measuring device. a) Detail of the mechanically scanned high aperture sonar profiler; b)View of IRIS installed in the support vessel.

So far, the MEDIRES project produced a pre-prototype of the high-accuracy measuring device that is presented in Figure. 1. It surveys only the submerged part of rubble-mound breakwaters. The figure shows a detail of the mechanically scanned high aperture sonar and the IRIS pre-prototype mounted on the support vessel.

Figure 4 shows that the survey produced by IRIS is quite comprehensive. Instead of an ensemble of surveys from sections along the breakwater, one has a very good scan of the armour layer (in this part of the structure alone 63969 points were surveyed). This large number of surveyed points implies a finer detail in the description of the armour slope, as can be seen in the figure.



a) Previous Survey



b) IRIS Survey

Figure 4. a) Perspective of the surface obtained with the points previously surveyed; b) Perspective of the surface obtained with points surveyed by IRIS.

A key point in that project is the development of IRIS - a measuring device for high accuracy surveys of both the submerged and emerged parts of those structures. The surveys obtained with the pre-prototype of IRIS, which is only able to survey the submerged part of the armour layer showed that a good scan of this part of the structure can be obtained.

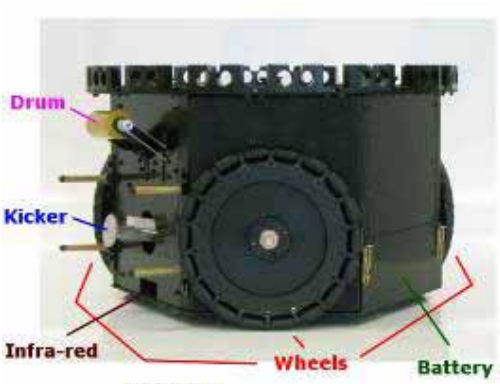
Research Areas: Real Time Architectures, Inertial Navigation, laser and acoutic mapping.
Laboratories: DSOR, VISLAB
External Partners: Laboratório Nacional de Engenharia Civil, Lisbon, Portugal. Administração do Porto de Sines, Sines Portugal. Autoridade do Porto de Avilez, Avilez, Espanha
Initiated: March 1, 2003
Expected conclusion: June 30, 2007
Classification: AdI (Agência de Inovação)
Documents produced in 2005: [109], [127]

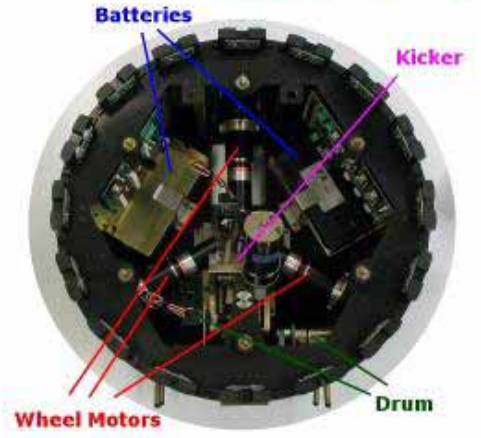
3.1.2 COOPERATIVE ROBOTICS

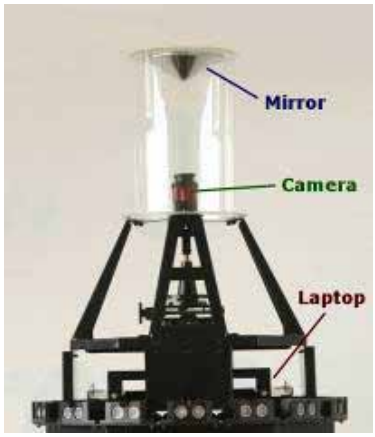
Project name: SocRob – SOCIETY OF ROBOTS OR SOCCER ROBOTS

Project leaders within ISR: Prof. Pedro Lima, Prof. Luis Custódio (IST / ISR)

Project description: This project fosters general research on multi-agent robotic systems, aiming at introducing methodologies for task planning, task allocation and teamwork supervision / coordination, driven by results from Distributed AI, Hybrid Systems and Discrete Event Systems theory. Its current case study is on Soccer Robots, with regular participations in RoboCup.







The FCT project started in 2003, and ended in this period, with two-folded contributions:

- **Technological**, because the new robots were professionally designed and manufactured, based on the past experience on RoboCup competitions of the leading institution (ISR / IST), as well as on the know-how and competence of the sub-contracted institutions (IdMind and ServoLog).
- **Scientific**, since some of the most recent research results of the ISocRob team (ISR / IST RoboCup MSL team) have been based on the expected availability of the new omnidirectional robots.

The option to involve Portuguese companies in the development of the robots was also successful, as new robotic prototypes, and relevant know-how were created in Portugal, instead of the simpler (but costly) solution of procuring existing solutions (not fitting the specifications of our design) made abroad. Although the main goal of this proposal was the development of robots specially designed to play soccer, the expected experience gathered from this project can now be re-used by the involved companies to build new commercially robotic solutions for other purposes rather than soccer, with financial and visibility side effects

for ISR/IST. Furthermore, the platforms have open hardware and software architectures, and can be sued by other groups at ISR/IST for general research on mobile robotics.
The new robots have most of their processing power concentrated on a NEC FS900 laptop, with an INTEL Centrino 1.6 GHz processor, with 512MB RAM and a 30GB disk. The laptop includes a CD-ROM, wireless 802.11b, 3 USB 2.0 ports, and 1 mini-firewire port, as well as a spare Li-Ion battery for extra autonomy.

Each robot is endowed with the following sensors:

- 1 AVT Marlin F-033C firewire camera;
- The camera is part of an omnidirectional catadioptric vision sensor, similar to the one used in the old robots;
- 16 sonars (SRF04 RangeFinder) disposed in a ring around the robot;
- 1 500 CPR encoder per motor for motor control and odometry;
- 1 AnalogDevices rate-gyro XRS300EB to improve orientation determination;
- 1 Creative Notebook Optical Mouse (800 dpi resolution and maximum speed of 1m/s) to improve position determination;
- 2 Sharp infrared sensors, to measure the kicker piston displacement and to detect the ball when it is between the robot fingers.

To power the electronics and motors, 2 packs of 9Ah NiMH batteries per robot are used, with a very good autonomy/weight ratio. IdMind has developed special chargers for these batteries, which allow charging the robots in maximum 3 hours, with the batteries in place, as well as running the batteries from DC current with a cable.
“Plug-and-play" connections of most peripherals to the laptop where decision-making, guidance and navigation algorithms are running were used.
Other contribution in this period focused on developing a dynamic programming algorithm to solve a class of Stochastic Games called two-person zero-sum games, inspired by the reinforcement learning algorithm Minimax-Q. In each state of the game, linear programming is used to find a Nash equilibrium, which ensures optimality in a worst-case scenario. The method is then applied to a behavioral model of a robotic soccer game. The goal is to find the worst case scenario strategy for such a team, so that a lower bound for the team’s performance is guaranteed.
One further tackled topic was a general formulation of relational behaviours for cooperative real robots and an example of its implementation using the pass between soccer robots of the Middle-Sized League of RoboCup. The formulation is based on the Joint Commitment Theory and the pass implementation is supported by past work on soccer robots navigation.

Research Areas: Cooperative Robotics, Sensor Fusion, Multi-Agent Systems, Teamwork, Discrete Event Systems
Laboratories: Intelligent Systems Lab
External Partners: IdMind, ServiLog
Initiated: January 1997, FCT funded project from October 2003
Conclusion: June 2005
Classification: FCT POSI/ROBO/43900/2002
Documents produced in 2005: [12], [13], [21], [38]

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Project name: SACOR – SEMI-AUTONOMOUS COOPERATIVE ROBOTS

Project leader within ISR: Prof. João Silva Sequeira (IST/ISR)

Project description: This projects aims at developing a distributed architecture to control multiple robots cooperatively, executing realistic missions with the help of human specialists. Foreseen practical applications include the assistance to the elderly and handicapped and remote surveillance and maintenance.

This project addresses the following topics: (1) synthesis of motion strategies (actions) supported on models of interactions among humans; (2) hybrid representation of the team state, with the discrete part of the state including event information exchanged among robots and specialists, and the continuous part of the state including the actions; (3) properties relevant from the mission execution perspective, namely controllability and stability, in the context of the hybrid systems addressed in topic (2). Topic (1) discusses the influence of

uncertainty in the synthesis of each of the robot's actions by selecting classes of controllers that make a differential inclusion (the action) viable in some pre-assigned set (the set bounding the possible trajectories in the robot's C-space). Topic (2) addresses the formal aspects of joining key results on non-smooth systems with those in hybrid systems theory. Topic (3) addresses the effect of negotiation models in team controllability and stability and on the formation of coalitions.

The project has now entered the final stage, with the preparation of a demonstration prototype. The application scenario is that of a robotic surveillance system, scaled down to an indoor laboratory experiment. This application scenario allows the testing of all the components developed along the project and the assessment of the coupling between them. Figure 1 illustrates the conceptual architecture that groups the main objects created within the project.

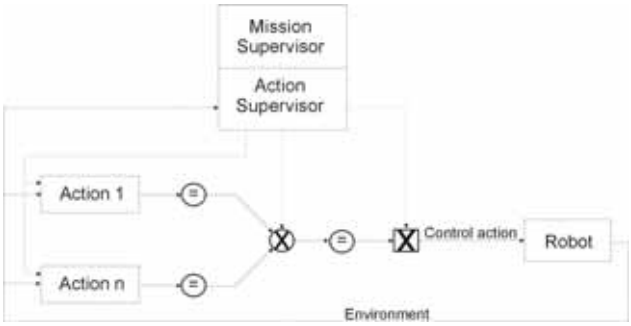

Figure 1: The SACOR conceptual architecture for the control of a semi-autonomous robot

The objects involved have been developed with the specific purpose of simplifying the interaction of human operators with the robots. The underlying human-robot interaction model is the sign model of semiotics, i.e., the objects in the architecture are mathematically modelled to mimic key characteristics of objects used by humans when interact among themselves such as semantics. These objects in the architecture are tailored to carry semantic content that is typically related to motion. Furthermore, they are used to form a sort of language that can be used by a non skilled human operator to interact with a robot.
The SACOR architecture is currently being tested in a laboratory environment at ISR. Figures 2 and 3 show a snapshots of the laboratory and the robots involved. Nomad Scout and Lego robots are being used. In addition, image agents placed in arbitrary (but fixed) positions in the ceiling of the laboratory provide the robots and human operators with feedback data that can be used both to define a mission and real time control.

Figure 2: The SACOR test environment

Figure 3: SACOR robots

The interaction between the human operators and robots is based on the mathematical objects in the control architecture namely the action bounding regions, i.e., regions in the workspace where the trajectory of a robot is constrained to stay in. Figure 4 shows a snapshot of the interface developed.

Figure 4: The SACOR HRI interface

The setup can be used to demonstrate basic robot control strategies in surveillance scenarios. Figure 5 shows a snapshot of a Scout robot moving to intercept an intruder (represented by the bright red box). Basic colour segmentation procedures were used in this experiment.

Figure 5: A Scout robot during the intruder approach phase

Figure 6 shows an example of a trajectory during a mission. The symbols * mark the points where an intruder was detected whereas the o indicate the final position of the robot (at the location of the intruder).

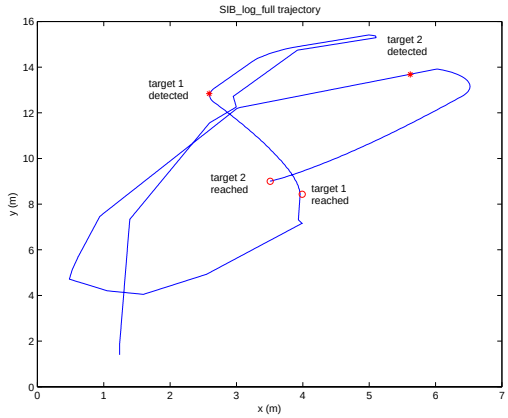

Figure 6: Example of a trajectory during a surveillance mission

Figure 7 shows an example of how the odometry of the robot is reset using the configuration obtained after the image data. The thin lines link the points before and after the odometry resetting. Thick lines correspond to standard odometry based robot navigation.

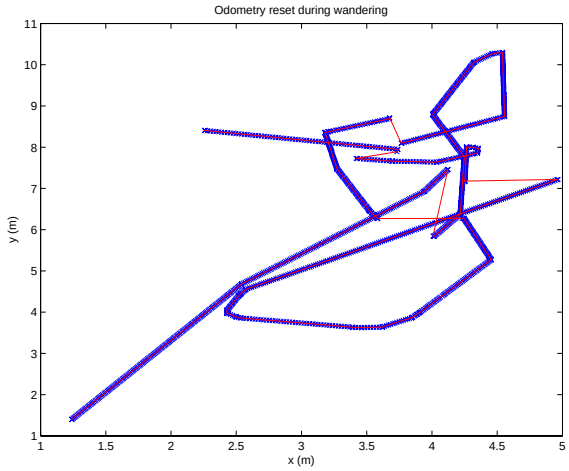

Figure 7: Odometry reset during a surveillance mission

Research Areas: Cooperative Robotics, Semi-Autonomous Robots, Hybrid Systems, Human-Robot Interaction
Laboratories: Mobile Robotics Lab
External Partners:
Initiated: September 2002
Expected Conclusion: October 2006
Classification: FCT POSI / SRI / 40999 / 2001
Documents produced in 2005: [17], [102], [139], [140]

3.1.3 ROBOTICS APPLICATIONS

Project name: RAPOSA – SEMI-AUTONOMOUS ROBOT FOR RESCUE OPERATIONS

Project leader: IdMind, Engenharia de Sistemas, Lda

Project leader within ISR: Prof. Pedro Lima (IST/ISR)

Project description: This project consisted of the design, development and test, in realistic scenarios, of a robot for Search and Rescue (SAR) operations, designed to operate in outdoors hazardous environments, such as debris resulting from structure collapses. At this stage, the robot is equipped for search operations only, defined as the tele-operated detection of victims, using specific sensors, whose information is transmitted to the remote operator. The robot is semi-autonomous, i.e., it is tele-operated from a remote station but simultaneously displays the capacity to carry out short tasks autonomously. The robot executes commands sent by a team of SAR experts, located in a safe place. During task execution, the robot relays the information from different sensors to the remote command station, so as to provide the human team with relevant information on its surrounding

environment (terrain conditions, temperature, dangerous gases, water or heat sources, either from human victims or not). The robot has a size designed in order to allow it to negotiate standard sized stairs and sewer pipes. Furthermore, it is a low weight, robust to collisions, dust and water infiltration vehicle.

During untethered operation, RAPOSA uses the onboard batteries and wireless communications to interface the operator. To recover the tether, the operator drives the robot backwards towards the cable, using the visual feedback of the web cam installed in the back side of the robot. After some maneuvering, the robot docks to the innovatively designed cable-end, and the operator latches the tether in using an onboard motorized device. After reaching some relevant location where the operation must be tether-free, the same motorized device latches the tether out by remote command. The cable supplies power and acts as a wireless access point. To the best of our knowledge, this remotely-operated cable docking system is a very useful innovative feature of RAPOSA.

The robot was tested in several scenarios of the Lisbon Fire Fighters school, in March 2005. One of the scenarios consisted of a 40m pipe hidden below a great amount of rubble, which the robot traversed entirely. Another scenario concerned the operation inside a two-floor house. The operator stayed outside and the robot was able to climb and descend stairs twice, as well as to undock and dock the power cable remotely. The robot did also traverse a dark tunnel with a step at the end.

The Lisbon Fire Department is willing to use RAPOSA in real operations. In October 2005, the robot was tested during an earthquake drill, performed at Sicily, Italy, joining several European Civil Protection institutions, at EUROSOT 2006. During the tests, the RAPOSA team and Lisbon firefighters had the opportunity to handle the operation of the robot in quasi-real scenarios, as well as the logistics involved in its quick transportation from Lisbon to the disaster scenario.

RAPOSA was also selected for participation in ELROB 2006, the 1st European Land-Robot Trial.

Research Areas: Semi-autonomous Robots, Search and Rescue
Laboratories: Intelligent Systems Lab, Mobile Robotics Lab
External Partners: Regimento de Sapadores Bombeiros de Lisboa (Lisbon Fire Department), Perceptual Robotics Laboratory of University of South Florida (USA)
Initiated: March 2003
Conclusion: March 2005
Classification: Agência de Inovação – Consortium Projects
Documents produced in 2005: [112]

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Project name: RIOL – ROBOTIC INSPECTION OVER POWER LINES

Project leader within ISR: Prof. João Silva Sequeira (IST / ISR).

Project description: The project aims at developing a prototype robot that uses the infrastructure provided by electric power lines for monitoring / maintenance tasks. Both the power lines and the shield wires provide structured environments for the locomotion of the robot enabling the monitoring of multiple parameters in areas of difficult orography such as in dense forestry.

The primary application for this robot is the inspection / maintenance of the power line infrastructure. Due to the exposure to different weather factors (e.g., sun, rain, wind and snow), materials loose electrical properties causing the disruption in energy distribution. Therefore, it is necessary from time to time, to carry out inspections, aiming at detecting any weakness in such electrical materials that may compromise the energy distribution. These are commonly being done mostly through helicopter based systems. The dangerous nature and the large economical requirements of such operation are pushing forward the development of alternative approaches.
Equally relevant applications of this robot are the monitoring of environmental parameters. The early detection of wild forest fires, environmental pollution and wildlife monitoring are possible with this robot. With multiple robots deployed over selected power lines it is possible to cover a wide area and in some cases to obtain multiple views of the same region.
The project is supported on preliminary studies on the dynamics of a basic serial structure. Using only two rigid links, in the absence of obstacles it is possible to generate a cabbage worm gait. This gait is adequate to the motion and transposition of most of the typical obstacles in the lines. A statically stable variation of the brachiating motion can be used to overcome the obstacles present in the lines. Simulation studies show promising results in the frame of some simplifying assumptions in the dynamic modelling.

The project encompasses studies on alternative kinematics, robust control strategies, control architectures and hardware requirements. For the two-link element, the torques required at the actuators tend to be high and hence the payload is severely reduced. Alternative kinematics using parallel structures are foreseen to be useful to reduce the torques needed.
When the lines are in operation the strong electromagnetic field in the neighbourhood of the lines requires special shielding techniques. Though the project primarily focuses on the locomotion aspects of the robot, the requirements on the materials and design of the electronic systems will be addressed.
Simulation of the resulting dynamics models under realistic environment conditions, including motion disturbances induced by atmospheric phenomena, will be used to assess the final characteristics of the prototype prior to production.

Figure 1 shows the basis kinematics scheme. A Lego prototype for this robot, shown in Figure 2, was successfully tested.

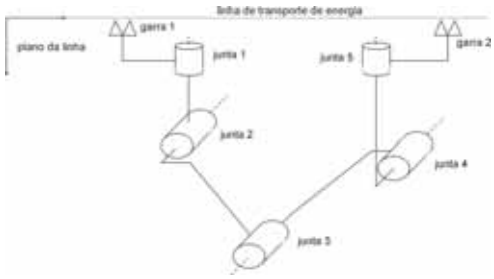

Figure 1: RIOL robot base kinematic structure

Figure 2 shows a prototype built in Lego. This robot was able to successfully demonstrate the basic locomotion principle.

Figure 2: Lego prototype for the RIOL robot

Research Areas: Modelling and Control of Robots, Hybrid Systems
Laboratories: Mobile Robotics Lab
External Partners:
Initiated: September 2005
Expected Conclusion: September 2008
Classification: FCT POSC / EEA-SRI / 60775 / 2004
Documents produced in 2005:

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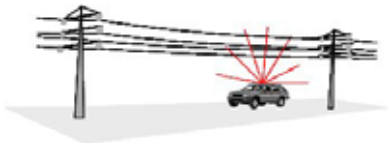
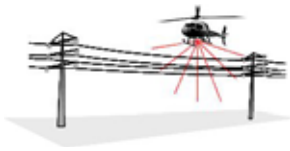
Project name: ACCURATE MEASUREMENTS OF HIGH VOLTAGE INSTALLATIONS WITH LASER RANGE SCANNERS AND GPS

Project leader within ISR: Profª Maria Isabel Ribeiro (IST / ISR).

Project description: Preventive detection of obstacle clearance infractions in power lines is important for electrical distribution and critical for transmission system operators. The project developed a prototype system to measure obstacle, in particular tree, clearance of high voltage electrical overhead lines based on laser scanning and performing on-line fault detection and classification.

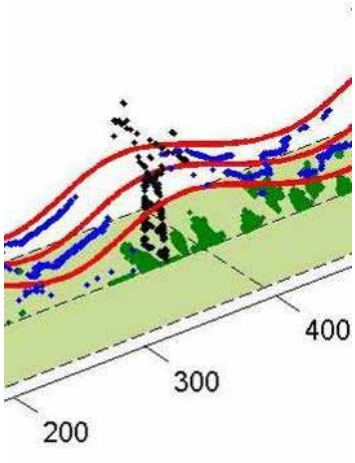
The system features a video-camera, a GPS-based geo-reference and a low-cost laser scanner with a one-dimension angle sweep, all installed in a land and in aerial vehicle (helicopter). The motion of the vehicle while the laser scans sweeps a three-dimensional volume around the overhead line, generates a cloud of 3D points that represent, the line, the poles and the nearest object to the laser on any scanned direction. Experiments have been carried with four-wheel drive land vehicles and, most often, helicopters.





This solution relies on human-machine interaction for optimal results: the pilot steers the vehicle according to the inspector directions, adjusting speed, attitude and course, depending on the environment along the line track. The line inspector's role is empowered by accurate measurements and a clearance fault diagnosis system that supports his / her assessment and focus the inspection on the critical spots, where he / she can acquire images and describe the scene by speech. The inspector must look for multiple faults along the line and the track. Thus, an optimized interface encompassing video, laser and grid layout is required not to hinder his performance.

The project developed an acquisition interface including laser, video and GPS data, a display interface, an algorithm to identify the line, the line supports and remaining obstacles from raw-data and a procedure to detect abnormal situations (e.g., obstacles closer to the line than a given threshold). Experiments were carried out with the sensors on board an all-terrain vehicle and on-board helicopter that performs the normal inspection operations for REN (National Electric Network).



Power line, support and remaining obstacles reconstructed from laser raw data acquired from an helicopter.

Real situation.

Research Areas: Monitoring and Surveillance
Laboratories: Mobile Robotics Lab
External Partners: LABELEC
Initiated: March 2005
Conclusion: November 2005
Classification:
Documents produced in 2005: [152]

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3.1.4 IMAGE PROCESSING

Project name: LTT – LONG TERM TRACKING OF MULTIPLE OBJECTS FOR SURVEILLANCE

Project leader within ISR: Prof. Jorge S. Marques (IST / ISR)

Project description: This project aims to develop methods for long term tracking of multiple objects in video sequences. Multiple object tracking has received the attention of the image processing community in the last 5 years, fostered by surveillance applications and by Model Based Video Coding (MPEG).
The first works addressed short-term tracking and recognition of activities. More recent works have tried to address long term tracking of moving objects. This is a more difficult problem since it involves the ability to disambiguate the trajectories of the objects after they were grouped and occluded for some time.
This project aims to address this problem. We wish to detect moving regions in video sequences and to develop algorithms to label each region in a consistent way along the whole video sequence. An additional difficulty concerns the presence of merged regions which can not be identified by a single label. Probabilistic models, namely probabilistic networks, will be adopted to perform this task and to propagate probable labelling scenarios. The tracking algorithms will be applied in the context of urban surveillance.

Research Areas: Image Processing, Surveillance
Laboratories: Signal processing Lab
External Partners: Polytechnic Institute of Lisbon
Initiated: 2002
Conclusion: 2005
Classification: FCT POSI / CPS / 37844 / 2001
Documents produces in 2005: [33], [80], [87], [90], [158]

Project name: AMA - AUTOMATIC MODELLING OF ARCHITECTURE

Project leader within ISR: Prof. Pedro M. Q. Aguiar (IST/ISR)

Project description: The goal of this project is to develop a new approach to the fully automatic 3D modelling of architecture from a video sequence.
The recovery of 3D structure (3D shape and 3D motion) from a video sequence has been widely addressed in the recent past by the computer vision community. The strongest cue to estimating the 3D structure from a video clip is the 2D motion of the brightness pattern in the image plane. For this reason, the problem is generally referred to as structure from motion (SFM). Early approaches to SFM processed a single pair of consecutive frames. Two-frame based algorithms are highly sensitive to image noise. More recent research has been oriented towards the use of longer image sequences. The problem of estimating 3D structure from multiple frames has a larger number of unknowns (the 3D shape and the set of 3D positions) but it is more constrained than the two-frame SFM problem because of the rigidity of the scene. The usual approach to multi-frame SFM relies on the matching of a set of feature points along the image sequence. Dense 3D shape estimates usually require hundreds of features that are difficult to track and that lead to a complex correspondence problem. Due to this difficulty, the automatic 3D modelling from video is still an open research problem.
This project attempts to overcome the difficulty outlined above by taking into account the more distinctive characteristic of common buildings - the flatness of their walls. The methods and algorithms to be developed within this project consider particular scenes whose 3D shape is well described by a piecewise planar model. Under this scenario, instead of tracking pointwise features, one can track larger regions where the 2D motion is described by a single set of parameters. The 3D structure of the scene is then computed from the 2D motion parameters. This approach avoids the correspondence problem and is particularly suited to constructing 3D models for buildings and urban scenes that are well described by piecewise flat surfaces.
The proposed project will lead to a method that is simultaneously a powerful tool to "virtualize" buildings and urban scenes and a further step into the development of artificial vision systems. Usually, constructing 3D scene descriptions suitable to virtual manipulation requires a lot of human interaction. The usefulness of the proposed method is due to the fact that it replaces the human interaction by a procedure that recovers 3D models from a video clip in a fully automatic way. That method can also be seen as a further step into the development of artificial vision systems because the piecewise planar assumption is valid as an approximation of the shape of the environment in more general scenarios. The approach to be followed in this project is then summarized in the following two steps:
Step i) From the video sequence, estimate the set of parameters describing the 2D motion of the image brightness pattern. The 2D displacement between two perspective views of the points that fall into a plane is given by a homography. The first part of the project will be devoted to the development of a new method to robustly estimate homographies from pairs of images.
Step ii) Given the set of parameters describing the 2D motion, compute the 3D shape of the scene and the 3D motion of the camera. The second part of the project concerns solving this large non-linear problem by using linear subspace constraints that proved to be efficient in related problems.

Research Areas: Image Processing, Computer Vision
Laboratories: Signal and Image Processing Group
Initiated: April 2002
Conclusion: April 2005
Classification: FCT POSI/SRI/41561/2001
Documents produced in 2005: [34], [35], [91]

3.1.5 UNDERWATER ACOUSTICS

Project name: NUACE – NON-CHOOPERANT UNDERWATER ACOUSTIC CHANNEL ESTIMATION

Project leader within ISR: Prof. Sérgio M. Jesus

Project description: Channel estimation is a common problem to many fields of research and,in particular, in underwater acoustics where the received signal is prone to severe time-space variability, strong multipath, dispersion and reverberation. Classical deconvolution methods attempt to estimate the parametric filter that best matches the medium response to a test input signal. These approaches mainly suffer from two well known drawbacks: one is the need for a known input signal, thus reducing its practical feasibility and efficiency and, two, is that the estimation process is started from scratch at each single environmental or

geometric change between source and receiver(s), what makes it extremely slow. This project intends to develop and test the experimental feasibility of environmental model-based methods to estimate the channel impulse response. Environmental model-based techniques are drawn from physical representations of the medium of propagation through the solution of the wave equation and boundary conditions. Searching for the environmental parameters that provide the best fit between the model-based replicas and the actual received signal can be viewed from three advantageous aspects: one is that there is no need for a known (deterministic) excitation of the medium, so the identification can be performed in a blind fashion, two, is that the search is reduced to the space covered by the solutions of
the wave equation thus, in principle closer to the true solution and three, each identified parameter has a physical meaning thus providing simultaneously, a possibility for including a priori information of its evolution in time and space, and an estimate of the physical medium itself with all its implications. A key aspect to be brought up in this project is that there is good evidence that signal and noise do propagate through the same channel, therefore noise acquires some modal structure and the signal gets a stochastic aspect. That explains the fact that, in a recent analysis of single hydrophone experimental data, it was found that the signal was confined to a subspace with a much smaller dimension than the expected dimension given by the model. Thus, taking advantage of this experimental fact, putting together the
information at each hydrophone throughout the array would be one of the goals of this project. In order to fullfil the project objectives, developing model-based techniques requires access to experimental facilities and actual at sea data. Therefore this project includes the at sea deployment of existing equipment, such as a 16-hydrophone vertical line array and an acoustic sound source, at fixed locations along the Portuguese coast, for listening both to controlled and uncontrolled sound sources (such as ships of opportunity) in various geometric configurations, along variable range-dependent and range-independent propagation transects and frequency bands.

Objectives:

- To develop optimization techniques for blind estimation of the environmental parameters that "focus" the source position and received to model data fitness. These parameters would provide the environmentally optimum channel impulse response at a given sensor;
- Extend that environmentally optimum channel impulse response to an array impulse response, by identifying the signal subspace at each sensor and subspace tracking throughout the sensor array;
- To test these techniques on at sea collected data, both under controlled and uncontrolled environments, for applications such as underwater communications, source localization and ocean acoustic tomography.

Research areas: Underwater Signal Processing / Communications
Laboratories: Signal and Image Processing Lab. (U. Algarve)
External Partners: CINTAL, Instituto Hidrográfico
Initiated: January 2004
Expected Conclusion: December 2006
Classification: FCT POSI / CPS / 47824 / 2002
Project Web page: www.ualg.pt / siplab / proj / nuace / nuace.html
Documents produced during 2005: [113], [129], [156], [157]

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Project name: **RADAR** – ENVIRONMENTAL ASSESSMENT WITH A RANDOM ARRAY OF ACOUSTIC RECEIVERS

Project leader within ISR: Prof. Sérgio M. Jesus.

Project description: This research project aims at the development and validation of acoustic remote sensing systems and inversion methods for the reliable, rapid environmental assessment (REA) of shallow water areas. One of the most promising REA concepts is to use a field of sonobuoys, deployed either from the air or from surface ship, to receive signals from a controlled sound source or sources of opportunity. The acoustic data, radio telemetered to the aircraft or ship, are processed to determine the range-dependent, water-column and bottom acoustic properties over the area spanned by the drifting buoys. The resulting environmental parameters integrated with concurrent oceanographic measurements are then used to initialize and calibrate oceanographic prediction models for nowcast and forecast environmental hazards in potential areas. The proposed research work directly stems from previous efforts carried at University the Bruxelles and at SACLANT Undersea Research Center for geoacoustic inversion techniques with random fields of sonobouys

and at University of Algarve, in the context of experimental testing of ocean acoustic tomography with sources of opportunity. In particular, proved concepts under static conditions, such as the use of a broadband coded signal propagated between a single sound source and a single hydrophone or a fixed array of hydrophones, will be extended to the dynamic configuration of freely drifting sonobuoys.

Objectives:

- Data-oriented segmentation and inversion algorithms for range-dependent, geoacoustic mapping and seabed characterization;
- Optimization algorithms for environmental focusing and water-column parameter estimation from the acoustic field received from non-cooperating sources on a random field of sonobuoys;
- Integration of on-site simultaneously measured oceanographic data as apriori information to constrain the tomographic inversion;
- Investigation of stochastic approaches to the signal processing and propagation modeling supporting the inversion of broadband acoustic
- signals.
- Study of sensitivity to bottom parameters and robustness against oceanographic and acoustic variability using existing SACLANTCEN datasets collected under diverse conditions;
- At-sea validation under complex environmental conditions and concluding on the capabilities and limitations of the proposed methods and their applicability under realistic at-sea operations.

Research areas: Ocean Acoustic Tomography / Signal Processing
Laboratories: Signal and Image Processing Lab. (U. Algarve)
External Partners: Instituto Hidrográfico
Initiated: October 2004
Expected Conclusion: September 2007.
Classification:
Project Web page: www.ualg.pt / siplab / proj / radar / radar.html
Documents produced during 2005: [129], [130]

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Project name: **AOBREA** – ACOUSTIC OCEANOGRAPHIC BUOY RAPID ENVIRONMENTAL ASSESSMENT

Project leader: E. Coelho (NATO Undersea Research Centre-NURC)

Project description: The proposed joint research project (JRP) aims at the development and validation of acoustic-oceanographic remote sensing systems and data inversion-integration methods for the reliable, rapid environmental assessment (REA) of shallow water areas.
In this project, adapted and newly developed air-dropped sonobuoys will have both acoustic and oceanographic sensors sparsely distributed in depth throughout the useful portion of the water column, referred herein as the AO-buoys. The collected data will be transmitted online to a processing platform that will integrate acoustic and oceanographic information in order to produce a verifiable and consistent parameterised image of the area under consideration. In an operational scenario, the resulting environmental parameters, combined with concurrent oceanographic measurements are (a) used in propagation models to predict conventional sonar performance, (b) exploited by environmentally-adaptive sonar systems to enhance their detection, localisation and classification capabilities and (c) used to initialise and calibrate high-resolution ocean models for nowcast and short-term forecast (say, up to 24 hours) of the environmental conditions in the area of interest.

Objectives:

The main objective is to demonstrate, with at-sea data, the feasibility of reliable REA with an acoustic-oceanographic buoy field. The focus will be on (a) the development of new methodologies to invert the acoustic signals and integrate satellite-sensed and in-situ oceanographic data, (b) the improvement of the existing design, including the integration of oceanographic sensors, additional hydrophones and self-recording capability, (c) data assimilation into high-resolution ocean models for short-term predictions consistent with the observed data and (d) the field test of the system.

Research areas: Marine Technology for Environmental Monitoring
Laboratories: Signal and Image Processing Lab. (U. Algarve)
External Partners: CINTAL, NURC, ULB, RNLNC, Instituto Hidrográfico
Initiated: January 2004
Expected conclusion: December 2006
Classification: FCT POCTI/CTA/47719/2002
Project Web page: www.ualg.pt/siplab/proj/aob_rea/aob_rea.html
Documents produced during 2005: [6]

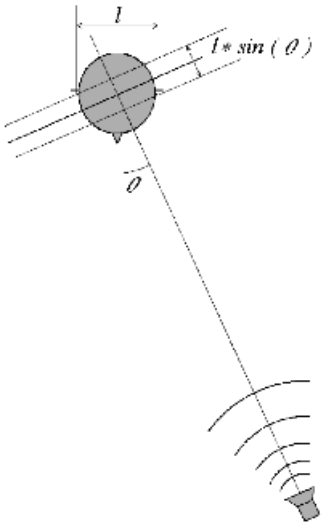
3.1.6 COMPUTER VISION

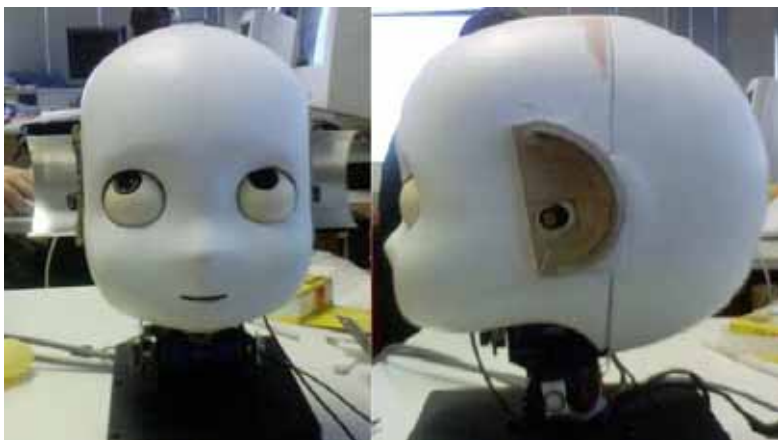
Project name: CONTACT - LEARNING AND DEVELOPMENT OF CONTEXTUAL ACTION

Project leaders within ISR: Prof. José Santos-Victor and
Prof. Alexandre Bernardino (IST/ISR)

Project description: As infants, each one of us developed the ability to move our muscles to manipulate objects and also to communicate with gestures and speech. Did we learn to perceive and produce gestures for manipulation and speech independently, or are these two learning processes linked? The CONTACT project is an ambitious attempt to investigate the parallel development of manipulatory and speech-related motor acts from a multi-disciplinary perspective. The project is designed to test the hypothesis that fundamentally similar mechanisms are involved in the development of perception and production for both speech and manipulation. This hypothesis is stimulated by recent evidence suggesting that the human brain interprets motor acts (movements) of other people in essentially the same way, regardless of wether the act generates speech or a manipulative gesture.

The work developed so far at IST consisted on sound source localization for the iCub head. For that purpose, the robot head was equipped with two microphones. The binaural sound difference (intensity or phase) is used for localization on the horizontal plane. Instead, for the vertical plane, the proposed method was based on the design of ear shapes similar to some extent to the human ears so that notches at different sound frequencies can be used as cues for the (vertical) localization of the sound.





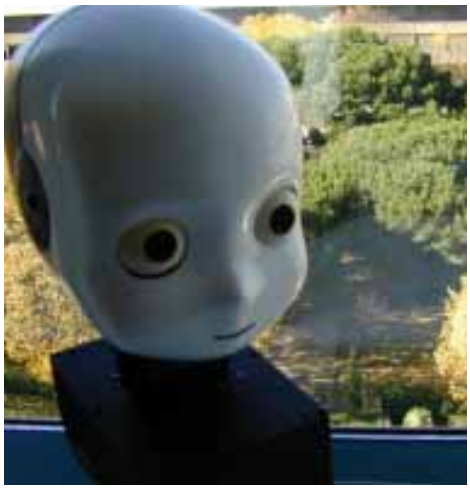
Research Areas: Computer Vision
Laboratories: Vislab - Computer Vision Lab
External Partners: IST; DIST, U.Genova (I); Dpt Psychology U. Uppsala (SE); Dept Human Physiology, U. Ferrara (I); Dpt Linguistics, U. Stockholm (SE)
Initiated: September 2005
Expected conclusion: August 2009
Classification: EU-NEST-5010
Documents produced in 2005:

Project name: ROBOT-CUB - ROBOTIC OPEN-ARCHITECTURE TECHNOLOGY FOR COGNITION, UNDERSTANDING AND BEHAVIOUR

Project leaders within ISR: Prof. José Santos–Victor and
Prof.Alexandre Bernardino (IST / ISR)

Project description: RobotCub is an Integrated Project funded by European Commission through the E5 Unit (Cognition) of Information Society Technologies priority of the Sixth Framework Programme. The consortium is initially composed of 11 European research centers plus two research centers in the USA and three in Japan specialized in robotics, neuroscience, and developmental psychology. The main goals of RobotCub are two: (1) to create an open robotic platform for embodied research that can be taken up and used by the research community at large to further their particular approach to the development of humanoid-based cognitive systems, and (2) to advance our understanding of several key issues in cognition by exploiting this platform in the investigation of cognitive capabilities. The scientific objective of RobotCub is, therefore, to jointly design the mindware and the hardware of a humanoid platform to be used to investigate human cognition and human-machine interaction. We call this platform CUB or Cognitive Universal Body. It is worth remarking that the results of RobotCub will be fully open and consequently licensed following a General Public (GP) license to the scientific community.

The team at IST is responsible for the design of the head of the iCub. The design specifications were based on the characteristics of the oculomotor system of children. This is the most complete robotic head for the given size. It consists of a three degrees of freedom (dof) eye sub-system and a three dof neck. The eyes can verge independently and tilt around a common axis. The neck can perform the pan-tilt-swing movements. The overall weight of the head is about 1.2Kg, motors included. All motors are equipped with encoders and the head possesses an inertial unit (the vestibular system). IST also worked on the design of the robot's face. The fact that the robot should act in a social environment to elicit communication with other robots and / or people was taken into account. The work on the face design was done in collaboration with the design company *Alma Design*. The picture below shows the designed robot head.



Research Areas: Computer Vision
Laboratories: Vislab - Computer Vision Lab
External Partners: IST; DIST, U.Genova (I); Arts Lab SSS, Anna (I); AI Lab U. Zurich (CH); Dpt Psychology U. Uppsala (SE); Dept Human Physiology, U. Ferrara (I); U.Hertfordshire (UK); U. Salford (UK); EPFL (CH); Telerobot S.r.l. (I); European Brain Research Institute (I)
Initiated: September 2004
Expected conclusion: August 2009
Classification: EU-IST-2004-004370
Documents Produced in 2005: [24], [41]

Project name: CAVIAR – CONTEXT AWARE VISION USING IMAGE-BASED ACTIVE RECOGNITION

Project leader within ISR: Prof. José Santos–Victor (IST / ISR)

Project description: The main objective is to develop the theory of context-aware visual recognition systems. We will implement the theory in a complete closed-loop vision system, and apply it to two applications (city street surveillance and customer behaviour analysis). To achieve these objectives, we will develop new feature grouping, attention and appearance-based recognition processes. This will also require development of new techniques for acquiring, representing and using visual context and situation knowledge. The work developed consisted mainly in two main areas:

- The use of Gabor filters for the detection of interest points and for the the representation of local image regions for posterior recognition.
- Feature selection and classifier design for the recognition of human activities from video.

Research Areas: Computer Vision
Laboratories: Vislab - Computer Vision Lab
External Partners: University of Edimburgh (UK); INRIA (F)
Initiated: October 2002
Conclusion: September 2005
Classification: EU-IST-2001-37540
Documents Produced in 2005: [47], [48], [49], [79], [82], [93]

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Project name: OMNISYS - OMNIDIRECTIONAL VISION FOR NAVIGATION AND CONTROL

Project leader within ISR: Prof. José Santos-Victor (IST / ISR)

Project description: The main objectives of this project are the study of problems related to robot perception and control using catadioptric systems. In particular visual servoing will include the use of uncalibrated images. The catadioptric systems that will be considered are central projection systems. The goals will include the development of mathematical models and coordinate systems that can simplify instances of servoing. The definition of features that can be robustly tracked with this type of images is also a goal of the project as well as the development of algorithms for servoing using partially calibrated or uncalibrated images. To reach this goal a systematic approach will be used. For that purpose a general mathematical model for perspective / catadioptric imaging formation will be established, covering the situations of vision system motion and the relative motions between the mirror and the imaging device that do not violate the central projection constraint.

Research Areas: Computer Vision, Mobile Robotics

Laboratories: VisLab – Computer Vision Lab
External Partners: ISR – Coimbra Pole
Initiated: September 2002
Conclusion: August 2005
Classification: FCT POSI / SRI / 41506 / 2001
Documents Produced in 2005: [72], [39]

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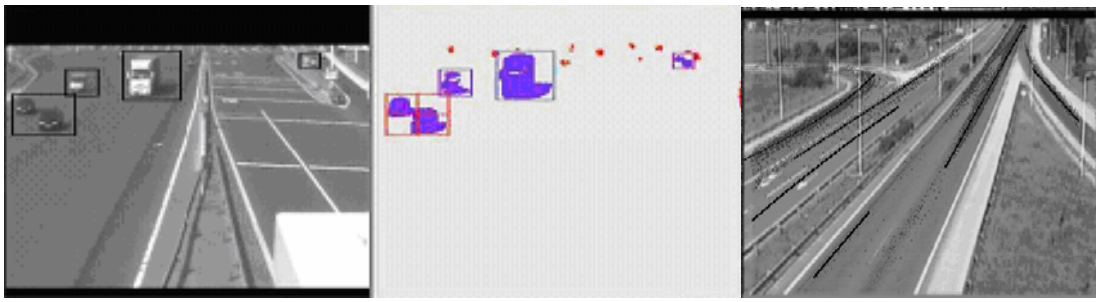
Project name: INTELTRAF – MONITORIZAÇÃO AUTOMÁTICA DO FLUXO DE TRÂNSITO AUTOMÓVEL E DETECÇÃO DE ACIDENTES E AVARIAS EM AUTO-ESTRADAS.

Project leader within ISR: Prof. José Santos –Victor (IST / ISR)

Project description: This project aims at developing an Automated Traffic Surveillance system with Computer Vision techniques. In a scientific and technological point of view we pretend to develop real-time algorithms for video sequence analysis of traffic scenes and explore innovative extended field of view camera systems (panoramic), with the final goal of price reduction and performance gain with respect to currently existing systems. In particular we address the applications of measuring traffic flow and detecting abnormal events on highways and critical urban areas. Traffic flow monitoring records statistical data on traffic distribution along time (number of vehicles, average velocity, average wait time on queues, etc.). We propose to develop a system that monitors a traffic region, acquires statistical data on traffic density and makes this data available on the Internet. Automatic event detection can help in speeding-up reaction to abnormal events, like accidents and serious transgressions to traffic rules. We propose to develop a system that detects abnormal events on critical traffic points, records the event history and send alarm signals to control stations.

Most of the work developed at IST consisted of estimating the highway lanes from the observation of traffic during a period of time. The method is based on a detection module and a tracker. The observed trajectories are input to a cluster algorithm defined in the trajectory space.



Research Areas: Intelligent Transportation Systems, Computer Vision
Laboratories: Vislab - Computer Vision Lab
External Partners: Observit, Tecnologias de Visão por Computador, Lda (P); Brisa, Auto-estradas de Portugal, SA (P); AITEK, SRL (I)
Initiated: September 2003
Conclusion: October 2005
Classification: POSI, Medida 1.3
Documents Produced in 2005:

Project name: VEMUCARV – SPATIAL VALIDATION OF COMPLEX URBAN GRIDS IN VIRTUAL IMERSIVE ENVIRONMENTS

Project leader within ISR: Prof. Alexandre Bernardino (IST / ISR)

Project description: The main goals of this project are related to the semi-automatic acquisition and maintenance of 3D virtual reality models of urban areas. It is intended to use registered aerial images and low altitude laser range scans to acquire 3D data of city structure. This data will be processed in order to segment relevant structures for urban planning (buildings, roads, green areas, etc). Range information provides a very rich description of 3D structure but lack photometric information. Aerial photos provide this information, allowing to pre-segment regions based on color and texture. The main scientific innovation of this project is the combined use of 2D (aerial images) and 3D (range scans) to simplify and improve the building extraction process. Most current approaches use one or the other types of data exclusively. The final result provides a computer model which stands for a mix geometry-image database that can interface to GIS software available (at CML), as well as the generation of real-time walkthrough with thematic information. The results of this project are to be integrated on Lisbon City Hall public computational facilities.

Research Areas: Computer Vision, Virtual Reality, Computer Aided Design, Geographical Information Systems
Laboratories: VisLab – Computer Vision Lab
External Partners: IDMEC-IST; CML
Initiated: May 2005
Expected conclusion: June 2008
Classification: FCT-POCTI / AUR / 48123 / 2002
Documents Produced in 2005:

3.1.7 UNMANNED AIR VEHICLES

Project name: **ALTICOPTER –** HELICÓPTERO NÃO TRIPULADO PARA ALTIMETRIA LASER (Unmanned Helicopter for Laser Altimetry)

Project leader within ISR: Prof. Carlos Silvestre (ISR / IST)

Project Coordinator: Prof. Carlos Silvestre (ISR / IST)

Project description: Today, some Unmanned Air Vehicles (UAVs) exhibit a high degree of reliability when operating in dynamic and uncertain environments and challenging operation scenarios. Among the many UAV configurations available today, helicopters are one of the most maneuverable and versatile platforms. They can takeoff and land without a runway and can hover in place. These capabilities have brought about the use of unmanned helicopters as highly maneuverable sensing platforms, allowing for the access to remote and confined locations without placing human lives at risk. For these reasons, there is currently great interest in using unmanned robotic helicopters in a wide range of applications that include crop spraying, hazardous spill inspection, fire surveillance, pollution monitoring, overhead power cables inspection, bridge and building construction inspection, etc.

This project focuses on the development of an unmanned robotic helicopter for precise airborne laser altimetry and surveying of disaster scenarios. The resulting system will be used to monitor the evolution of sand dunes and beaches as well as to demonstrate the usefulness of these platforms in disaster scenarios. Motivated by the high accuracy requirements of the envisaged applications as well as by the highly complex, coupled, and unstable dynamics of the helicopter, a whole range of research topics are being addressed within the framework of Alticopter.

- Sensor based control for autonomous vehicles: Development of control laws that can react directly to sensor data in real time. The control strategies consist of converting the motion control problem into that of driving to zero a generalized error, defined in a suitable sensor set error space. Within the context of this topic, a laser based terrain following controller has already been designed and evaluated in simulation.
- Path following controllers for extended flight envelope maneuvers: Study of control strategies to drive the helicopter along arbitrary paths in 3D, namely paths that can involve sudden changes on the platform's angle

of attack (e.g. 0 to 90 degrees). The theoretical tools required to address these problems borrow from nonlinear scheduling control theory.
- Real-time distributed architectures for mission and vehicle control: Study and development of architectures to simplify the task of performing the concerted operation of the different systems resident on board autonomous vehicles.

Figure 1. Vario Xtreme Helicopter equipped with control electronics. Left) Helicopter ready to takeoff; Right) Detail of the control electronics and motion sensors.

Figure 1 shows the Vario Xtreme model-scale Helicopter during the tests that took place in May 2004. These open loop tests with onboard instrumentation were carried out for acquisition of flight test data needed to calibrate the helicopter dynamic simulator.

An additional helicopter platform, the new Bergen R/C Industrial Twin shown in Figure 2. As shown in the figure, a new reinforced landing gear designed at ISR was fitted to the platform to better accommodate and isolate from vibration all onboard instrumentation. The Bergen Industrial Twin is capable of lifting a 11Kgf payload for one half hour on a tank of gas. The Industrial twin uses a twin cylinder Bergen/Zenoah - 52cc engine, producing about 8 horsepower. A single carb manifold is used for ease of mixture adjustment. A large, high efficiency fan is in place to provide cooling for the engine. Power is transmitted through a heavy duty double clutch and clutchbell to a twin main gear. A fully hardened 10mm hollow mainshaft turns the all aluminum head and fully ballraced aluminum blade grips. Symmetrical 810 mm V-Blades provide the lifting power. The Industrial Twin Features an aluminum torgue tube to transmit power to the aluminum tail gearbox with delrin gears and 130 mm tail blades.

Figure 2 Bergen Industrial Twin Helicopter with modified landing gear.

Research Areas: Nonlinear dynamic modeling, Guidance and Control, Inertial Navigation, Laser and Vision Mapping
Laboratories: DSOR, VISLAB
External Partners: Instituto Geológico e Mineiro, Lisbon, Portugal
Initiated: May 1, 2002
Conclusion: December 31, 2005

Classification: FCT – Sapiens
Documents produced in 2005: [61], [77], [76], [122], [126], [144]

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Project Name: **ObservFly**

Project Coordinator: Prof. Carlos Silvestre (ISR / IST)

Project description: The primary objective of the ObservFly Project is to equip a large (3.5 m wing span) radio-controlled model airplane, developed by and property of CavadasAeromodelismo, with avionic systems that will be able to autonomously steer the airplane through a series of predefined smooth trajectories with the goal of recording image data from a wireless camera installed on board. The avionics is vibration isolated from the fuselage using a soft suspension mechanism, which acts as a mechanical low pass filter to provide further attenuation of the aircraft vibration on the electronics. The avionics hardware is built using the low power high performance floating point Texas Digital Signal Processor (DSP) TMS320C33, which is connected to the data acquisition hardware through a dual port RAM expansion board. The onboard distributed architecture is being built around the CAN (Controller Area Network) Industrial Real Time Network. Communication with the ground station is done resorting to a Serial Link Internet Protocol over a wireless modem that allows for transmission of the aircraft status (attitude, linear and angular position, airspeed, etc.) and reception of uplink commands from the ground station in real-time. A simulation model of the Aircraft Dynamics named SimAirDyn, is also being developed and tuned for the ObservFly platform. SimAirDyn is an accurate mathematical model suitable for effective control system design and flight envelope expansion. The Airplane is modeled as a six degrees of freedom rigid body, actuated by forces and moments that are generated at the propeller, fuselage, and wings. The remaining components, namely the landing gear and the antennas, which have a smaller impact on the overall behavior of the aircraft dynamic model, are not included in the simulator and will be treated as disturbance by the control system. The Inertial Navigation System onboard the platform will use the algorithms developed within the scope of the ASAINS project The navigation information together with the airspeed are transmitted through the downlink at a transmission rate of 1 Hz. From the Guidance and Control System point of view the Aircraft operation modes relevant for the project are autonomous takeoff, accurate stationary flight, and landing. The first two flight conditions involve controlling the platform using the information provided by the navigation system. The last and critical flight condition is the automatic landing. The controller for automatic landing will be developed using a sensor based approach. To improve the airborne data acquisition quality, special emphasis will be placed on developing 3-D guidance and control systems for accurate path following and trajectory tracking.

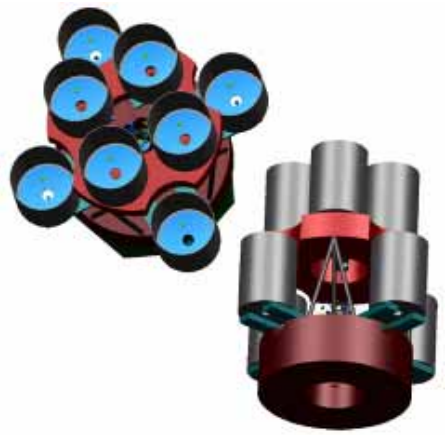
Aircraft Characteristics: The Aircraft is capable of lifting a 11Kgf payload for two hours on a tank of gas, The Wingspan is 3.5m and the length is 1.8m and has a takeoff distance half load of 50m. It uses a one cylinder two stroke- 60cc engine, producing about 8 horsepower.

Research Areas: Nonlinear dynamic modeling, Guidance and Control, Inertial Navigation, Laser and Vision Mapping.
Laboratories: DSOR
Initiated: September 1, 2005

Conclusion: December 31, 2008
Classification: Internal Project
Documents produced in 2005:

3.1.8 SPACE APPLICATIONS

Project name: HIGH RESOLUTION OPTICAL SATELLITE SENSORS



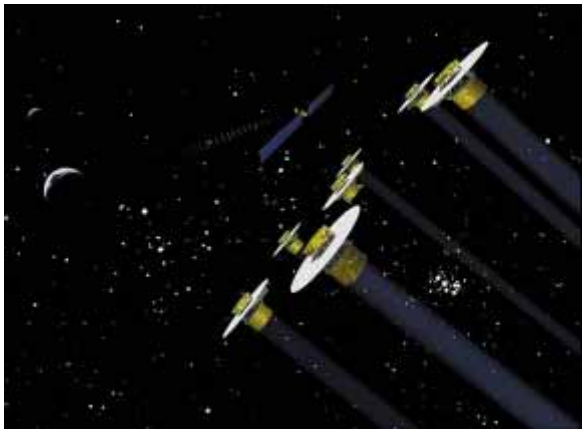
Project leader: Alenia Spazio (Italy)

Project leader within ISR: Prof. Pedro Lima (IST / ISR)

Project description: The main objective of this project is to develop a High Resolution Optical Satellite Sensor (HROSS) by using the synthetic aperture technique. This technique consists in the reconstruction of the original image of an object starting from that formed on the common focal plane of a set of telescopes (or a multi-aperture telescope) observing simultaneously the object while maintaining constant within a fraction of wavelengths the phase of the various wavefronts which are combined together (namely, a set of telescopes correctly co-phased, which, in this case, operate like an interferometer). The synthetic aperture technique thus allow to obtain the same resolution of a monolithic-mirror by means of a set of smaller mirrors properly arranged over the surface covered by the monolithic one, with a dramatic reduction of the volume and the mass of the optics.
In this period, ISR contributed with the specification, design and simulation of the overall HROSS control system, based on the available data concerning the GEO instrument overall metrology system specifications, the co-phasing demonstrator (under development by Alenia Spazio) characteristics, including sensors and noise transmission through the bench structure, the noise-to-co-phasing transfer function characteristics for a spacecraft structure similar to the GEO instrument, the performance requirements for the active co-phasing control loop, and the nominal parameters of the actuator mechanisms to be used by the control loop. Simulation results were presented covering the individual OPD pair controllers, providing indications for the parameterization of the corresponding control loop, its sensors and actuators. Two possible strategies for controlling the overall instrument were suggested.

Research Areas: Satellite Formations, Non-linear Control, Interferometry Techniques
Laboratories: Intelligent Systems Lab
External Partners: Alenia Spazio (Italy); INETI (Portugal); CSL (Belgium); AMOS (Belgium); MICROMEGA (Belgium)
Initiated: November 2003
Conclusion: December 2005
Classification: EUCLID - RTP 9.09
Documents produced in 2005: [115]

Project name: FORMATION ESTIMATION METHODOLOGIES FOR DISTRIBUTED SPACECRAFT



Project leader within ISR: Prof. Pedro Lima (IST/ISR)

Project description: This project consists of a literature survey followed by the proposal, development and test, in simulation, of an extension of the traditional Guidance, Control and Navigation loop for a single spacecraft to a set of spacecraft flying in formation. This extension creates some novel challenges, since each spacecraft can be considered an obstacle for its team-mates, especially during formation initialisation, relative or absolute information about the formation state can be considered, both state estimation and control can be centralized/distributed or decentralized and do not necessarily need to be tied to the actual topology of the spacecraft formation.
A preliminary study was carried out so as to identify different approaches to the state estimation and control of spacecraft formations, as well as to compare them according to different criteria such as fuel consumption, fuel distribution across the spacecraft, robustness to spacecraft failure, communication link failure, individual sensor failure or temporary occlusions of either communications or sensor reading.
Following that study, ISR/IST developed an integrated approach to GNC of formation flying spacecraft. The Navigation algorithm estimating the full relative state of all the spacecraft is a full-order decentralized filter, based on an Extended Kalman Filter for local measurements, and on Covariance Intersection for the fusion between local state estimates and estimates communicated by other spacecraft, eliminating EKF divergence problems. For Guidance and Control, an algebraic closed-loop algorithm, based on Pontryagin's maximum principle, is proposed, minimizing the propellant consumption and ensuring collision avoidance. This algorithm is regularly recomputed. Simulations of the GNC algorithms for a GTO 3-spacecraft formation, supported by a very realistic simulator developed by the partner DEIMOS, were carried out successfully, and an extension of the project was awarded by ESA, where the formation attitude estimation is now being studied.

Research Areas: Satellite Formations, Formation Control, Multi-vehicle State Estimation, Multi-Agent Coordination Architectures
Laboratories: Intelligent Systems Lab
External Partners: DEIMOS Engenharia (PO)
Initiated: July 2003
Expected Conclusion: March 2006
Classification: ESA (European Space Agency) 17529/03/NL/LvH/bj
Documents produced in 2005: [63], [111], [154]

3.1.9 AERONAUTICS

Project name: ROSAS - RESEARCH ON SILENT AIRCRAFT CONCEPTS

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Industrial Research Project, funded by European Union, under 5th Framework Programme, 3rd call, Promoting Competitive and Sustainable Growth/Key Action Aeronautics. Role of IST: modelling the effect of the wing in shielding the noise from the engines.

Research Areas:
Laboratories: Aeronautics Group
External Partners: EADS
Initiated: 2002
Conclusion: 2005
Classification:
Documents produced in 2005:

Project name: VELA – VERY EFFICIENT LARGE AIRCRAFT

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Industrial Research Project, funded by European Union, 5th Framework Programme, 3rd call, Promoting Competitive and Sustainable Growth/Key Action Aeronautics; Role assessments of the stability of flying wing aircraft.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners: EADS
Initiated: 2002
Conclusion: 2005
Classification:
Documents produced in 2005:

♦

Project name: X-NOISE – AIRCRAFT EXTERNAL NOISE NETWORK PHASE II

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Role of IST: support task 5: Scientific Exchanges.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners: Snecma-France
Initiated: 2002
Conclusion: 2005
Classification:
Documents produced in 2005:

♦

Project name: NEFA – NEW EMPENAGE FOR AIRCRAFT

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Role of IST: assessment of coupling of longitudinal and lateral stability.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners: Airbus France
Initiated: 2003
Conclusion: 2005
Classification:
Documents produced in 2005:

♦

Project name: SEFA - SOUND ENGINEERING FOR AIRCRAFT

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Role of IST: model of aircraft noise and effects of atmospheric propagation.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners: Dornier
Initiated: 2004
Expected Conclusion: 2006
Classification:
Documents produced in 2005:

♦

Project name: FRIENDCOPTER – INTEGRATION OF TECHNOLOGIES IN SUPPORT OF A PASSENGER AND ENVIRONMENTALLY FRIENDLY HELICOPTER

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Role of IST: model of helicopter noise and ground effects.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners: Eurocopter
Initiated: 2004
Expected Conclusion: 2006
Classification:
Documents produced in 2005:

♦

Project name: NACRE – NEW AIRCRAFT CONCEPTS RESEARCH

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Role of IST: airframe noise shielding and cruise drag minimization.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners: Airbus
Initiated: 2005
Expected Conclusion: 2008
Classification:
Documents produced in 2005:

♦

Project name: TAA – AERODYNAMIC AND AEROACOUSTIC WIND TUNNEL

Project leaders within ISR: Prof. L. M. Braga Campos (IST/ISR)

Project description: Installation of anechoic chamber at aerodynamic wind tunnel at Aeronautics Laboratory at IST, together with force and moment balance, fluid dynamics and acoustic instrumentation and data acquisition system.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners:
Initiated: 2005
Expected Conclusion: 2006

Classification:
Documents produced in 2005:

♦

Project name: SVI – RESEARCH FLIGHT SIMULATOR

Project leaders within ISR: Prof. L. M. Braga Campos (IST / ISR)

Project description: Installation of a 6 degree-of-freedem research flight simulator with Fokker F.27 Friendship cockpit in Aeronautics Laboratory at IST.

Research Areas: Aeronautics
Laboratories: Aeronautics Group
External Partners:
Initiated: 2005
Expected Conclusion: 2006
Classification:
Documents produced in 2005:

3.2 POST-DOCS ACTIVITIES REPORTS

3.2.1 Activity report of DAN DUMITRIU

Period: July 2004 to October 2005
Fellowship: ESA (European Space Agency) Project "Formation Estimation Methodologies for Distributed Spacecraft". Ref. 17529/03/NL/LvH/bj
Advisor: Prof. Pedro Lima

Guidance and Control of Satellite Formations

Under the framework of the ESA project, an optimal trajectory planning algorithm that balances the fuel spent and the need for collision avoidance among the formation spacecraft was developed for a GTO demonstration mission, composed of 3 formation flying spacecraft. This algorithm computes the spacecraft trajectories from the knowledge of the formation dynamics and full state, therefore it is a model-based trajectory planner, that provides not only the optimal trajectories but their corresponding optimal control thrusts. The optimal control law is derived using Pontryagin's maximum principle formulation, providing some advantages with respect to existing methods, mainly due to the possibility of including non-linear dynamics terms. By re-computing the trajectory at regular time intervals, formation control is also accomplished. The Guidance and Control (GC) was implemented and tested in a Matlab/Simulink formation flying dynamics simulator, developed by DEIMOS. The implemented GC algorithm computes a quasi-optimal (which does neither consider collision avoidance nor the non-linear perturbation terms), simple and robust-to-perturbations algebraic solution. The control inputs limitations and collision avoidance are considered a posteriori, so as to avoid using any time consuming iterative technique. For the moment, perturbations are not considered by the algorithm. Perturbations must be linearized first in order to be included in the algorithm.

Documents produced in 2005:

[A] **D. Dumitriu, P. Lima, B. Udrea**, "Optimal Trajectory Planning of Formation Flying Spacecraft", *Proc. of 16th IFAC World Congress*, Prague, Czech Republic, July 2005.

[B] **P. Lima, A. Caramagno, J. C. Bastante, D. Dumitriu, S. Marques, L. F. Peñin, J. A. Silva**, "Formation Estimation Methodologies for Distributed Spacecraft – Phase II Final Report", March 2005.

[C] **D. Dumitriu, S. Marques, P. Lima, B. Udrea**, "Decentralized, Low-Communication State Estimation and Optimal Guidance of Formation Flying Spacecraft", *16th AAS/AIAA Space Flight Mechanics Conference*, Tampa, FL, USA, January 2006 (accepted).

3.3.2 Activity Report of JACINTO NASCIMENTO

Period: September 2004 to December 2005
Fellowship: CAVIAR project *Context Aware Vision using Image-based Active Recognition* - Surveillance (EU, IST-2001-37540)

My post-doctoral research is taking place at ISR, funded by FCT (with the scholarship SFRH/BPD/9409/2002). During this year my work is related with above research project. Next I will summarize the contents of the project.

Research topic:

HUMAN ACTIVITY RECOGNITION AND MODELLING

Objective (CAVIAR project):

CAVIAR, *Context Aware Vision using Image-based Active Recognition* - Surveillance (EU, IST-2001-37540).

The main objective is to develop the theory of context-aware visual recognition systems. We will implement the theory in a complete closed-loop vision system, and apply it to two applications (city street surveillance and customer behavior analysis). To achieve these objectives, we will develop new feature grouping, attention and

appearance-based recognition processes. This will also require development of new techniques for acquiring, representing and using visual context and situation knowledge.

Major Results:

The results of my research work can be summarized in the following publications:

Ongoing papers:

[A] **J. Nascimento, M. Figueiredo, J. S. Marques**, "On-line inspection of human activities".

[B] **J. Nascimento, J. S. Marques**, "EM semi-supervised learning for surveillance of human activities".

Submitted papers:

[C] **J. Nascimento, M. Figueiredo, J. S. Marques**, "Independent increment processes for human motion recognition", *Computer Vision and Image Understanding.*

Published papers:

[D] **Jacinto C. Nascimento, Mário A. T. Figueiredo, J. S. Marques**, "Segmentation and Classification of Human Activities", *Proc. of HAREM2005 - Workshop on Human Activity Recognition and Modelling, held at BMVC2005*, pp. 79-86, Oxford, UK, September 2005.

[E] **J. Nascimento, M. Figueiredo, J. S. Marques**, "Recognition of human activities using space dependent switched dynamical systems", *Proc. ICIP2005 - IEEE International Conference on Image Processing*, Genoa, Italy, September 2005.

[F] **D. Hall, J. Nascimento, P. Ribeiro, E. Andrade, P. Moreno, S. Pesnel, T. List, R. Emonet, B. Fisher, J. Santos-Victor, J. Crowley**, "Comparison of target detection algorithms using adaptive background models", *Proc.* VS-PETS - *2nd Joint IEEE Internationmal Workshop on Visual Surveillance and Performance Evaluation of Tracking and Surveillance, held at ICCV2005*, pp. 113-120, Beijing, China, October 2005.

[G] **J. Nascimento, J. S. Marques**, "Adaptive snakes using the EM algorithm", *IEEE Transactions on Image Processing*, Vol. 14, No. 11, pp. 1678-1686, November 2005.

3.2.3 Activity Report of VÍTOR VIEIRA LOPES

Period: October 2005 - January 2006
Fellowship: FCT Post-Doctorate grant
Advisor: Prof. Agostinho Rosa

Description of activities:

The post-doc main work theme is the development of biological system simulations based on the complex systems framework. Emphasis is being put on the development of algorithms that can exploit the inherent parallelism of modern graphical processing units (GPU).

During this period, the main research effort was focused on two main issues:

- development of image processing techniques that can be used to image enhancement and the reconstruction of three-dimensional objects from static scenes. Currently, feature matching algorithms based on information theory are being implemented by making use of modern GPU processing capabilities and tested on different image scenery (mobile camera, home camera, medical images);
- development of a complex simulation system to describe the human imune system, co-orienting a master thesis work.

Documents produced:

[A] **R. C. Martins and V. V. Lopes**, "Modeling supercooling in frozen strawberries: experimental analysis, cellular automation and inverse problem methodology", *Journal of Food Engineering* (accepted).

[B] **R. C. Martins and V. V. Lopes**, "Maximizing the supercooling effect in frozen strawberries", *International Journal of Refrigeration* (submitted).

3.2.4 Activity Report of FERNANDO GÓMEZ BRAVO

Period: May – July 2005
Fellowship: Spanish Science and Technology Foundation
Advisor: Prof. M. Isabel Ribeiro

Description of activities:

Along the months of May, June and July of 2005, Prof. Fernando Gómez Bravo (from the University of Huelva, Spain) stayed at the Institute for Systems and Robotics (ISR), in the Instituto Superior Técnico (IST). He worked, supervised by Prof M. Isabel Ribeiro, in a research project concerning cooperative navigation and localization techniques.

The problem suggested to overcome consisted on the study of the localization and motion strategy of a team of robot in a mission of planet surface exploration.

Particularly, Prof. Gómez, coordinated with Dr. Vale (ISR), proposed a new strategy for cooperative localization of a team of robots based in a probabilistic technique known as the Particle Filter approach (P.F.). The work developed a set of motion strategies in order to improve the robots localization and the execution of the mission.

The cooperative localization technique relies on distance and orientation measurement among the robots and the robots and a fixed beacon. It is also considered that the beacon has sensorial capabilities. The robots and the beacon present a limited range detection along a limited field of view. Even more, the measurements of the robots and the beacon present uncertainty. Thus, the real measurement and the model of the sensors uncertainties are taken into account by means of the P.F. technique in order to obtain an estimation of the pose of each robot.

The mission consists on the path following of a closed trajectory. The team navigation also involves obstacle avoidance for each robots and a motion strategy where one of the robot, the master, follows a pre-specified path and the other team-mates, the slaves, have a constrained motion aimed at having the master in a visible detectable range.

The proposed approach was tested by the execution of several experiments that illustrates the good performance of the algorithms.

Some of the results obtained in this work have been presented in a paper titled "Particle-Filter Approach and Motion Strategies for Cooperative Localization" which will be submitted to the ICINCO conference. Future papers will illustrate the full dimension of the approach.

As a conclusion, the stay of Prof. Gómez Bravo has been a fruitful experience, allowing the visiting professor to acquire a valuable knowledge on a new field of robotic research. Even more, it fosters the present and future relation between the University of Huelva and the ISR/IST. Prof. Gómez Bravo wants to give thanks to the ISR team and especially to Prof. Ribeiro and Dr. Vale for their personal interest and invaluable help along the stay.

Documents Produced:

[A] **F. Bravo, A. Vale, I. Ribeiro**, "Particle – Filter Approach and Motion Strategy for Cooperative Localization", *Proc. of ICINCO2006 – 3rd International Conference on Informatics in Control, Automation and Robotics*, Setúbal, Portugal, August 2006 (accepted for publication).

3.3 THESES

In this section the Doctoral and Master theses concluded, or in progress, during 2005 at ISR-Lisbon are identified.

3.3.1 THESES CONCLUDED DURING 2005

DOCTORAL THESES (3)

Paulo S. Felisberto, "Data Fusion Applied to Ocean Acoustic Tomography", Ph.D. Thesis, University of Algarve, Portugal, April 2005.

Abstract:

This thesis discusses the application of data assimilation methods to the estimation of space-time disturbances of the temperature/sound speed field in coastal environments. The proposed method is based on the assimilation of data measured in-situ and data provided by acoustic tomography, in accordance with an acoustic field correlation model commonly used in oceanography. The assimilation method developed herein uses information provided by classical ray tracing acoustic tomography. In order to overcome the stringent requirements imposed by ray tracing based acoustic tomography regarding source-receiver geometry knowledge, an alternative method of data assimilation based on range independent matched field tomographic inversions is proposed. This method is applied to an acoustic data set acquired during an internal wave devoted study: the INTIMATE'98 sea trial. The analysis of the experimental data set acquired during INTIMATE'98, allowed for realistic setup of a simulated temperature/sound speed space-time disturbances field, than used as input to the data assimilation simulation study. This work is a contribution to implement a strategy of sampling oceanographical processes, combining methods of underwater acoustics and methods of oceanography, in order to simplify acquisition systems and provide faster access to oceanographic information.

Keywords:

Data Assimilation, Ocean Acoustic Tomography, Inverse Problems.

Members of the Thesis Committee:

Prof. Sérgio M. Jesus, UALG (P)
Prof. Antonio Pascoal, IST (P)
Emanuel F. Coelho, NURC (I)
Paulo Relvas, UALG (P)
Prof. Orlando Rodriguez, UALG (P)
Yann Stephan, CMO-SHOM (F)

Alberto Manuel Martinho Vale, "Mobile Robot Navigation in Outdoor Environments: A Topological Approach", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2005.

Abstract:

The thesis addresses the problem of mobile robot navigation in outdoor environments and proposes methodologies based on a topological approach, concerning to three main issues: environment representation, localization and navigation. The selected approach, based on a mathematical support, has to solve the three main issues simultaneously.
The motivation of the thesis is based on some cutting edges of the nature, where are millions of species with fantastic navigation capabilities, that retrieve the essential for life.
For this purpose, complete algorithms were developed and tested in realistic scenarios with a real mobile robot. The main contributions of the thesis are the environment representation (a new topological representation, a set of notes defined by sum of Gaussians, connected by orientation), map building (a dynamic version of expectation and maximization algorithm), a probabilistic approach for localization and navigation (an optimized version of forward-backward algorithm) and feature extraction and selection (different types of feature extraction procedures with a selection criteria).

The thesis concludes in a chapter describing the experimental results acquired by a real mobile robot, showing that the developed algorithms achieve the main goals proposed by a topological approach and a high level of abstraction.
The main contribution provided in the thesis is the definition and demonstration of the applicability of mobile robot navigation in unstructured environments based on a high level of abstraction, supported on a topological map and providing topological navigation and localization of the robot.
This work is concerned on a search and rescue like project, "RESCUE - Cooperative Navigation for Rescue Robots", where the main goal is to provide integrated solutions for the design of cooperative robots teams operating in outdoor environments.

Keywords:

Navigation, Mobile Robots, Topological Map, Probabilistic Robotics, Feature Extraction and Selection, Search and Rescue, Outdoor Environments.

Members of the thesis committee:

Prof. João Miranda Lemos, IST (P)
Prof. José Neira Parra, University of Zaragoza (SP)
Prof. Maria Isabel Ribeiro, IST (P)
Prof. Jorge Manuel Miranda Dias, University of Coimbra (P)
Prof. Mário Figueiredo, IST (P)
Prof. Pedro Lima, IST (P)

Fernando Manuel Fernandes Melício, "Horários Escolares Semanais por Simulated Annealing", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2005.

Abstract:

Automated Timetabling in every school of Portugal is the main goal of this work. The key issues in any automated timetabling systems are addressed. The definition of a generic and flexible model for all kinds of schools is introduced. The work is carried out with the data of 62 Portuguese schools. An efficient way for computing the cost function is shown. Local search methods are applied with significant success. New neighbourhood operators are studied and compared their results. A new measure for the efficiency for any algorithm is introduced. The results from three different schools are analysed and compared. The quality improvement obtained with this system is shown.

Keywords:

Timetabling, Schools, Heuristics, Local Search, Neighbourhood, Combinatorial Optimization.

Members of the thesis committee:

Prof. João Miranda Lemos, IST (P)
Prof. Joaquim Júdice, FCTUC (P)
Prof. João Sentieiro, IST (P)
Prof. Luís Correia, FCUL (P)
Prof. Luís Miguel Silveira, IST (P)
Prof. Agostinho Cláudio da Rosa, IST (P)
Prof. Luís Custódio, IST (P)

MASTER THESES (5)

Nuno Paulino, "Terrain Tracking Control Strategies for Autonomous Vehicles with application to Unmanned Helicopters", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, March 2005.

Abstract:

This thesis addresses the problem of terrain following by a model-scale helicopter equipped with a Laser Range Scanner that provides information about the terrain profile ahead the vehicle. The methodology used to solve the terrain following control problem amounts to convert it into it as a discrete time path following control problem where state space model of the plant is augmented with the terrain preview data.
The path following control problem is then converted into an equivalent regulation problem of a conveniently defined generalized error space. Using the fact that the generalized error dynamics is time invariant along straight lines, the error dynamic is linearized and discretized, and the problem is then posed and solved under the scope of gain-scheduling control theory. The synthesis problem of each linear controller associated to each state space operating region is stated as a discrete time state feedback H2 control problem and solved using Linear Matrix Inequalities. The feedforward gain matrix is then computed using a proposed sub-optimal technique that avoids solving Linear Matrix Inequalities involving a large number of unknowns. This methodology naturally leads to an integrated guidance and control system design technique for terrain following, where the stability around equilibrium or trimming trajectories contained in the several pre-defined operating regions is guaranteed. The thesis introduces a technique to build the reference path given the terrain profile information provided by the sensor where the characteristics of the future reference are transformed into a deterministic disturbance - preview disturbance - to be used in the feed-forward part of the preview controller. The overall performance of the terrain following integrated guidance and control system is evaluated in simulation with a full non-linear model of a model-scale helicopter.

Members of the thesis committee:
Prof. Maria Isabel Ribeiro, IST (P)
Prof. José Sá da Costa, IST (P)
Prof. Aníbal Ollero, University of Seville (SP)
Prof. Carlos Silvestre, IST (P)

Vasco Miguel Yones Coutinho Pires, "Sistema de Decisão Distribuído Baseado em Lógica para uma Equipa Multi-Robot", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, July 2005.

Abstract:

Nowadays, we can see an increasing amount of robotic systems for purposes of continuously growing complexity. Some of these applications require, not just a single robot, but a group or team of robots that must work together to accomplish the goal. This raises some problems related to the coordination of several robots that must be handled accordingly.
Robotics has improved in many ways. Mechanics are becoming faster, more precise, reliable and durable. Electronics provides greater autonomy, reliable sensors, and faster processing. Artificial vision endows robots with the ability to detect objects in the world by just looking at them with video cameras, with no special extra sensors. But, even with all this great new technology, a big problem remains: how to decide what the robot should do? A robotic arm can pick up a glass of water without spilling it, but when should it do that? Why should it do that? Will picking up the glass help to accomplish the goal? This is why the link between Robotics and Artificial Intelligence (AI) is becoming more relevant every day. Robotics provides the means to interact with the real world. Artificial Intelligence allows a robot to decide over that world.
In this thesis a distributed decision system for a team constituted by several agents is described. The system uses logic for planning a sequence of actions that will accomplish a pre-determined goal and react to environment events. It also supports cooperation to better achieve the goal. This system is applied in a multi-robot team that participates in the international event called RoboCup.

Keywords:

Decision Systems, Multi-Agent Systems, Cooperative Autonomous Robots

Members of the Thesis Committee:

Prof. Luís Correia, FCTUNL (P)
Prof. Pedro Lima, IST (P)
Prof. Luís Custódio, IST (P)

José Inácio Rocha, "Inspecção e Manutenção Robótica em Linhas de Transporte de Energia Eléctrica de Alta Tensão", M.Sc. Thesis, Instituto Superior Técnico, Lisboa, Portugal, September 2005.

Abstract:

This thesis presents a viability study for a robot to navigate in a structured environment (overhead power lines) carrying out periodical inspection / maintenance tasks on electric power lines. In addition, monitoring and surveillance tasks such as forest patrolling, environmental mapping and wild life monitoring.
The robot has a basic double-pendulum kinematic structure and uses a statically stable variation of the brachistochrone motion to move along electric shield wires / electric power lines overcoming the obstacles present in electrical structures.
The proposed approach stands on two main motivations, (i) to reduce the costs of current maintenance and inspections strategies used in power lines, and (ii) to reduce the danger inherent to these tasks when performed by humans.

Keywords:

Surveillance / Maintenance / Inspection Robots, Power Lines, Pendulum Robot.

Members of the thesis committee:

Prof. Maria Isabel Ribeiro, IST (P)
Prof. Joaquim Norberto Cardoso Pires da Silva, University of Coimbra (P)
Prof. João Silva Sequeira, IST (P)

Ricardo Marranita, "Visual Tracking of articulated objects: an application to the human hand", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2005.

Abstract:

Tracking articulated objects is important in areas such has Medicine, Robotics or Computer Graphics. A particular application is tracking human movement. This thesis proposes a vision-based method to track finger movements on a sequence of images. The goal is to determine the value of the angles in the articulations of the fingers.
The approach comprises several steps. A kinematic model of the hand is used to describe some of the physical limitations of finger movements. The model is first used to guide the extraction of local image measurements corresponding to the finger parts.
This image analysis can be done in four different ways, where the best one is designed to handle finger occlusion. A pose estimation algorithm adjusts the kinematic model to the observations retrieved from the image. Finally, temporal integration is used to reduce estimation uncertainty and predict the hand appearance in the next image frame.
Tests performed on different steps show their performance and limitations. Results show successful tracking on real and synthetic images using the two best performing techniques. These tests range from simplified to complete hand models. Conclusions and further direction of work are described in the end.

Keywords:

Hand tracking, occlusion, kinematic model, non-invasive tracking, image sequence, Kalman filter.

Members of the thesis committee:

Prof. Arnaldo Castro Abrantes, ISEL (P)
Prof. Alexandre José Malheiro Bernardino, IST (P)
Prof. José Santos-Victor, IST, Orientador Científico (P)

Nelson Ricardo Perdigão Pereira, "Hybrid Evolutive Algorithm for Multiple Sequence Alignment", M.Sc.Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2005.

Abstract:

Multiple Sequence Alignment (MSA) is one of the most important tools in bioinformatics. The MSA problem is NP-hard, therefore heuristic approaches must be developed to align sequences in a reasonable amount of time.
In this thesis the heuristic approach used was evolutionary hybrid algorithms which are a combination of evolutionary algorithms with dynamic programming (with local and global search of alignments between pairs of subsequences) to find suboptimal alignments with a reasonable quality.
To evaluate the quality of the alignments produced one use benchmark alignments from BALiBASE. BALiBASE is a database of optimal multiple alignments that were produced manually. This database was specially built for performance evaluation of multiple alignment programs.

Keywords:

Multiple Sequence Alignment, Hybrid Algorithms, Proteins, Evolutionary Algorithms, Dynamic Programming, BALiBASE.

Members of the thesis committee:

Prof. Luís Correia, FCUL (P)
Prof. Arlindo Oliveira, IST (P)
Prof. Agostinho Cláudio da Rosa, IST (P)

3.3.2 THESES IN PROGRESS DURING 2005

In this subsection the Doctoral and Master theses in progress during 2005, at ISR / IST (ECE) and ISR / Algarve (ECE), are identified and ordered by the scientific research area.

DOCTORAL THESES (41)

Research Area: State Estimation for Satellite Formations
Title: Decentralized Navigation Methods for Formation Flying Spacecraft
Doctoral Student: Sónia Marques
Advisor: Pedro Lima
Initiated: September 2001
Expected conclusion: 2006
Current Status: On-going, finished PhD coursework
Documents produced in 2005: [154]

Research Area: Discrete-Event Based Modelling and Coordination of Robotic Tasks
Title:
Doctoral Student: Hugo Costelha
Advisor: Pedro Lima
Initiated: October 2003
Expected conclusion: 2007
Current Status: On-going, finished PhD coursework
Documents produced in 2005:

Research Area: Multi-Agent Reinforcement Learning for Stochastic Games
Title:
Doctoral Student: Gonçalo Neto
Advisor: Pedro Lima
Initiated: October 2003
Expected conclusion: 2007
Current Status: On-going, finished PhD coursework
Documents produced in 2004: [38]

Research Area: Discrete-Event Based Opponent Modelling
Title:
Doctoral Student: Abdolkarim Pahliani
Advisor: Pedro Lima
Initiated: February 2005
Expected conclusion: 2009
Current Status: On-going
Documents produced in 2005:

Research Area: Artificial Intelligence
Title: Emotion-based Agents
Doctoral Student: Rodrigo Ventura
Advisor: Carlos Pinto-Ferreira
Initiated: 2001
Expected conclusion: 2006
Current Status: On-going
Documents produced in 2005:

Research Area: Computer Vision
Title: Vision based imitation
Doctoral Student: Manuel Cabido Lopes
Advisor: José Santos-Victor
Initiated: 2002
Expected conclusion: 2006
Current Status: Submitted
Grant:
Documents produced in 2005: [24], [41]

Research Area: Computer Vision
Title: Recognition using Biological inspired filters.
Doctoral Student: Plinio Moreno Lopez
Advisor: José Santos-Victor
Initiated: 2002
Expected conclusion: 2006
Current Status: On-going
Grant: FCT
Documents produced in 2005: [48], [82], [93]

Research Area: Computer Vision
Title: Recognition of Human Activities from video
Doctoral Student: Pedro Canotilho Ribeiro
Advisor: José Santos-Victor
Initiated: 2003
Expected conclusion: 2007
Current Status: On-going
Grant: FCT
Documents produced in 2005: [49], [79], [93]

Research Area: Computer Vision
Title: Audio-video integration
Doctoral Student: Jonas Hörnstein
Advisor: José Santos-Victor
Initiated: 2005
Expected conclusion: 2008
Current Status: On-going
Grant: CAVIAR Project
Documents produced in 2005:

Research Area: Computer Vision
Title: Image matching
Doctoral Student: Ricardo Oliveira
Advisor: João Paulo Costeira
Initiated: 2001
Expected conclusion: 2006
Current Status: On-going
Grant: FCT
Documents produced in 2005: [45], [46]

Research Area: Cooperative Robotics
Title: Learning Cooperative Navigation in the Absence of Communication
Doctoral Student: Francisco António Saraiva de Melo
Advisor: Isabel Ribeiro
Initiated: 2003
Expected conclusion: 2006
Current Status: On-going
Grant: FCT PhD grant SFRH / BD / 3074 / 2000
Documents produced in 2005: [11], [110], [134], [153]

Research Area: Hybrid Systems
Title: Yet to be defined
Doctoral Student: Nelson Gonçalves
Advisor: João Silva Sequeira
Initiated: 2005
Expected conclusion: 2008
Current Status: Ongoing
Grant: FCT PhD grant SFRH / BD / 23804 / 2005
Documents produced in 2005:

Research Area: Guidance and Control of Dynamical Systems
Title: Sensor-Based Guidance and Control of Robotic Vehicles
Doctoral Student: Rita Cunha
Advisor: Carlos Silvestre
Initiated: 2001
Expected Conclusion: 2006
Current Status: On-going
Grant: FCT Graduate Scholarship
Documents produced in 2005: [61], [76], [122], [144]

Research Area: Control and Navigation of Autonomous Vehicles
Title: Integrated Design of Navigation and Control Systems for Autonomous Vehicles
Doctoral Student: José Vasconcelos
Advisor: Carlos Silvestre and Paulo Oliveira
Initiated: 2004
Expected Conclusion: 2008
Current Status: On-going
Grant: FCT Graduate Scholarship
Documents produced in 2005: [77]

Research Area: Control Theory
Title: Coordinated Path Following Control of Multiple Autonomous Vehicles
Doctoral Student: Reza Ghabcheloo
Advisor: António Pascoal / Carlos Silvestre
Initiated: 2002

Expected Conclusion: 2006
Current Status: On-going
Grant: FCT Graduate Scholarship
Documents produced in 2005: [57], [98], [100], [132], [133], [145], [148]

Research Area: Navigation
Title: Landmark-Based Navigation of Autonomous Underwater Vehicles (AUVs) using Bathymetric and Geomagnetic Information.
Doctoral Student: Francisco Curado Teixeira
Advisor: António Pascoal (IST) / Hipólito Monteiro (Geological Survey of Portugal – IGM)
Initiated: 2001
Expected Conclusion: 2006
Current Status: On-going
Grant: FCT Graduate Scholarship
Documents produced in 2005: [97], [119], [137]

Research Area: Control Theory
Title: Robust Adaptive MIMO Control using Multiple-Model Hypothesis Testing and Mixed Mu-Synthesis
Doctoral Student: Sajjad Fekri Asl
Advisor: Michael Athans / António Pascoal
Initiated: 2002
Expected Conclusion: 2006
Current Status: On-going
Grant: FCT Graduate Scholarship
Documents produced in 2005: [58], [131], [147]

Research Area: Navigation and Positioning Systems
Title: Navigation and Positioning Systems for Underwater Robots using Nonlinear Estimation Techniques
Doctoral Student: Alex Alcocer Peñas
Advisor: Paulo Oliveira / António Pascoal
Initiated: 2004
Expected Conclusion: 2008
Current Status: On-going
Grant: FCT Graduate Scholarship
Documents produced in 2005: [118], [135], [136], [146]

Research Area: Guidance and Control of Dynamic Systems
Title: Terrain Avoidance Control for Robotic Helicopters
Doctoral Student: Bruno Guerreiro
Advisor: Carlos Silvestre
Initiated: 2005
Expected Conclusion: 2009
Current Status: research in progress
Documents produced in 2005:

Research Area: Array Signal Processing in Underwater Acoustics
Title: Array processing for ocean acoustic tomography on range-dependent environments.
Doctoral Student: Cristiano Soares
Advisor: Sérgio M. Jesus
Initiated: February 2002
Expected conclusion: December 2006
Current status: On going
Grant: FCT Doctoral fellowship
Documents produced in 2005: [113], [128], [150]

Research Area: Signal Processing
Title: Oceanic parameter estimation using multi-dimensional representations of acoustic signals
Doctoral Student: Nelson Martins
Advisor: Sérgio M. Jesus
Initiated: September 2002
Expected conclusion: 2006
Current status: On going
Grant: FCT Doctoral fellowship
Documents produced in 2005:

Research Area: Underwater Acoustic Communications
Title: Environmentally robust methods for underwater acoustic communications
Doctoral Student: António João Silva
Advisor: Sérgio M. Jesus
Initiated: July 2003
Expected conclusion: 2007
Current status: On going
Grant: Teaching Assistant (PRODEP fellowship)
Documents produced in 2005: [113], [129], [130]

Research Area: Evolutionary Systems – Optimization and Image Enhancement
Title: Increasing Adaptability in Evolutionary Algorithms for Solving Complex Optimization Problems
Doctoral Student: Cristian Munteanu
Advisor: Agostinho Cláudio da Rosa
Initiated: Jan 2001
Expected Conclusion: March 2006
Current Status: scheduled for 2006
Grant: FCT
Documents produced in 2005: [16], [104]

Research Area: NeuroSciences
Title: Physiological Modeling and characterization of olfactive discrimination in rats
Doctoral Student: Ernesto Soares
Advisor: Agostinho Cláudio da Rosa
Initiated: July 1999
Expected Conclusion: 2006
Current Status: delivered for discussion
Grant: Calouste Gulbenkian Foundation
Documents produced in 2005:

Research Area: Biomedical Engineering - Neuroscience
Title: Biological Intelligent Machine Learning
Doctoral Student: José Luís Malaquias
Advisor: Agostinho Cláudio da Rosa
Initiated: September 2000
Expected Conclusion: 2006
Current Status: delivered for discussion
Grant:
Documents produced in 2005:

Research Area: Artificial Life – Social Systems
Title: Agentes autónomos com capacidade de cooperação: Desenvolvimento e aplicações.
Doctoral Student: Osvaldo Brasão
Advisor: Agostinho Cláudio da Rosa
Initiated: July 1999
Expected Conclusion: 2006
Current Status: Delivered for defense

Grant: FCT
Documents produced in 2005:

Research Area: Biomedical Engineering
Title: Análise da Microestrutura do EEG do Sono por ondeletas e Sintonia do detector por Computação Evolutiva
Doctoral Student: Rogério Largo
Advisor: Agostinho Rosa
Initiated: 2005
Expected conclusion: 2007
Current Status: on-going
Grant: EST-IPS
Documents produced in 2005: [29], [54], [85], [104]

Research Area: Artificial Life – Evolutionary Systems
Title: Metodologias Evolucionistas na protecção e gestão de colheitas
Doctoral Student: Gong Hongfei
Advisor: Agostinho Cláudio da Rosa
Initiated: October 1999
Expected Conclusion: 2006
Current Status: on-going
Grant: FCT
Documents produced in 2005:

Research Area: Biomedical Engineering
Title: A Bio-computational model of the human vision
Doctoral Student: Raquel César
Advisor: Agostinho Rosa
Initiated: 2004 (at ISR only from June 2005)
Expected Conclusion: 2007
Current Status: on-going
Grant: FCT
Documents produced in 2005: [30], [84]

Research Area: Evolutionary Algorithms
Title: Antropologic Evolutionary Algorithms
Doctoral Student: Carlos Fernandes
Advisor: Agostinho Rosa
Initiated: December 2004
Expected Conclusion: 2008
Current Status: on-going
Grant: FCT
Documents produced in 2005: [15], [31]

Research Area: Evolutionary Algorithms
Title: Parallel Evolutionary Algorithms
Doctoral Student: João Paulo Caldeira
Advisor: Agostinho Rosa
Initiated: December 2005
Expected Conclusion: 2009
Current Status: on-going
Grant: EST-IPS
Documents produced in 2005: [28], [42], [53]

Research Area: Evolutionary Algorithms
Title: Linguistic modelling by Evolutionary Algorithms

Doctoral Student: Rui Tavares
Advisor: Agostinho Rosa
Initiated: October 2005
Expected Conclusion: 2009
Current Status: on-going
Grant: UE
Documents produced in 2005:

Research Area: Wireless Communications
Title: Non-coherent communication for multiple-antenna wireless systems
Doctoral Student: Marko Beko
Advisor: João Xavier
Initiated: 2004
Expected conclusion: 2007
Current Status: On-going
Grant: FCT
Documents produced in 2005:

Research Area: Computational Learning
Title: Classificação de documentos usando aprendizagem baseada em núcleos
Doctoral Student: André T. Martins
Advisors: Mário A. T. Figueiredo, Pedro M. Q. Aguiar
Initiated: 2005
Expected conclusion: 2008
Current Status: On-going
Grant: FCT
Documents produced in 2005:

Research Area: Queuing Networks
Title: To be defined
Doctoral Student: Nuno Manuel dos Santos Órfão
Advisor: Carlos Bispo
Initiated: 2002
Expected conclusion: 2006
Current Status: Preparing proposal
Grant:
Documents produced in 2005

Research Area: Computer Sciences – Human Vision / Computer Vision / Visual Psychophysics
Title: Multi-scale integrated cortical architecture with applications in computer vision
Doctoral Student: João Rodrigues
Advisor: Hans du Buf
Initiated: 1998
Expected Conclusion: December 2006
Current Status: on going
Grant: PRODEP III Medida 5 - Acção 5.3 from April 2004 - September 2006
Documents produced in 2005: [94], [95], [83], [73], [74], [50]

Research Area: Computer Sciences – Computer Graphics
Title: 3D object Reconstruction and Triangulation
Doctoral Student: Roberto Lam
Advisor: Hans du Buf
Initiated: 2001
Expected conclusion: 2008
Current Status: on going
Grant:
Documents produced in 2005: [73], [83]

Research Area: Computer Sciences – Human Vision / Computer Graphics
Title: Not yet available
Doctoral Student: Pedro Guerreiro
Advisor: Hans du Buf
Initiated: 2005
Expected conclusion: 2010
Current Status: on going
Grant:
Documents produced in 2005:

Research Area: Image processing in 3D
Title: 2D and 3D data Processing and visualization
Doctoral Student: Edward Loke
Advisor: Hans du Buf
Initiated: 1998
Expected conclusion: 2007
Current Status: writing thesis
Grant: European project ADIAC, ISACS and EXOCET / D
Documents produced in 2005: [51]

Research Area: Computer Sciences – Human Vision / Computer Graphics
Title: Robust face recognition by 3D cortical representations
Doctoral Student: Samuel Nunes
Advisor: Hans du Buf
Initiated: 2005
Expected Conclusion: 2010
Current Status: on going
Grant: UE - EXOCET / D
Documents produced in 2005: [51], [83], [96]

Research Area: Computer Sciences – Human Vision / Computer Vision
Title: Eye tracking, focus of attention and shading in 3D face recognition
Doctoral Student: Daniel Almeida
Advisor: Hans du Buf
Initiated: 2005
Expected conclusion: 2010
Current Status: on going
Grant: UE – EXOCET / D
Documents produced in 2005: [51], [83], [96]

MASTER THESES (13)

Research Area: Artificial Intelligence
Title: Emotion-based Agent Architectures
Master Student: Bruno Damas
Advisor: Luis Custódio
Initiated: 2002
Expected conclusion: January 2006
Current Status: Waiting discussion
Documents produced in 2005:

Research Area: Artificial Intelligence
Title: Task Planning and Execution for a Multi-robot Team
Master Student: Miguel Arroz
Advisor: Luis Custódio
Initiated: 2003

Expected conclusion: 2006
Current Status: Waiting discussion
Documents produced in 2005:

Research Area: Artificial Intelligence
Title: Cooperative Learning in a Multi-Agent System
Master Student: Constança Sousa
Advisor: Luis Custódio
Initiated: 2004
Expected conclusion: 2006
Current Status: On-going
Documents produced in 2005: [44], [65], [108]

Research Area: Multi-Robot Systems
Title: Formation Control of Aerial and Land Vehicles
Master Student: Pedro Fazenda
Advisor: Pedro Lima
Initiated: 2004
Expected conclusion: 2007
Current Status: On-going, finished coursework
Documents produced in 2005:

Research Area: Computer Vision
Title: Stereo Reconstruction of a Submerged Model Breakwater and Interface Estimation
Master Student: Ricardo Ferreira
Advisor: João Paulo Costeira
Initiated: 2004
Expected conclusion: 2006
Current Status: on-going
Grant:
Documents produced in 2005:

Research Area: Cooperative Robotics
Title: Yet to be defined
Master Student: João Casaleiro
Advisor: Isabel Ribeiro
Initiated: 2004
Expected conclusion: 2006
Current Status: Ongoing
Grant:
Documents produced in 2005:

Research Area: Petri nets, Discrete Event Systems, Human-Robot Interaction
Title: Yet to be defined
Masters Student: José Carlos Ribeiro
Advisor: João Silva Sequeira
Initiated: 2004
Expected conclusion: 2006
Current Status: Ongoing
Grant:
Documents produced in 2005:

Research Area: Real time networks systems
Title: Yet to be defined
Masters Student: Pedro Manuel Sousa Guimarães
Advisor: João Silva Sequeira (Co-advisor)

Initiated: 2005
Expected conclusion: 2007
Current Status: Ongoing
Grant:
Documents produced in 2005:

Research Area: Real Time Systems
Title: Real Time Architectures for Autonomous Vehicles
Master Student: João Alves
Advisor: Carlos Silvestre
Initiated: October 2002
Conclusion: 2006
Current Status: submitted during 2005
Grant:
Documents produced in 2005: [109], [124]

Research Area: Real Time Navigation Systems
Title: Real Time Architectures for Inertial Navigation Systems with application to Autonomous Vehicles
Master Student: Bruno Cardeira
Advisor: Carlos Silvestre / Paulo Oliveira
Initiated: 2004
Expected conclusion: November 2006
Current Status: research in progress
Grant: Project MEDIRES, AdI
Documents produced in 2005

Research Area: Control of Autonomous Vehicles Systems
Title: Laser Based Obstacle Avoidance Guidance and Control Techniques for Unmanned Catamarans
Master Student: Pedro Gomes
Advisor: Carlos Silvestre / António Pascoal
Initiated: November 2005
Expected conclusion: June 2007
Current Status: research in progress
Documents produced in 2005

Research Area: Biomedical Engineering
Title: Processamento de imagens em microscopio confocal
Master Student: Alexandre Calapez
Advisor: Agostinho Rosa
Initiated: 2002
Expected Conclusion: 2006
Current Status: on-going
Grant:
Documents produced in 2005:

Research Area: Biomedical Engineering
Title: Sistema Imunitário Artificial
Master Student: Nuno Fachada
Advisor: Agostinho Rosa
Initiated: 2005
Expected Conclusion: 2006
Current Status: on-going
Grant:
Documents produced in 2005:

3.4 ADVANCED TRAINING

3.4.1 COURSES

José Santos-Victor – "Statistical and Computational Models of Vision", Ph.D. Course, Instituto Superior Técnico, Lisbon, Portugal.

João Xavier – "Nonlinear Signal Processing", Ph.D. Course, Instituto Superior Técnico, Lisbon, Portugal.

Pedro Lima - "Artificial Intelligence", M.Sc. Course, Post-Graduation on Electrical and Computers Engineering at IST, Lisbon, Portugal.

Paulo Oliveira – "Dynamic Stochastic Estimation, Prediction, and Smoothing", a one semester Ph.D. Course, previously taught together with Prof. Michael Athans, Instituto Suerior Técnico, Lisbon, Portugal.

Carlos Silvestre – "Design of Robust Multivariable Feedback Control Systems", a one semester Ph.D. Course taught together with Prof. Michael Athans, Instituto Superior Técnico, Lisbon, Portugal.

A. Pedro Aguiar – "Nonlinear Systems", a one semester Ph.D. Course, Instituto Superior Técnico, Lisbon, Portugal.

Agostinho Rosa – "Análise Automática da Polisonografia do Sono", M.Sc. Course in Sleep Medicine, Faculdade de Medicina da Universidade de Lisboa, Lisbon, Portugal, June 2005.

3.4.2 SEMINARS

• During 2005 the following Seminars were given outside ISR:

Margarida Silveira – "Processamento de imagem médica", Seminário sobre Tecnologias Biomédicas aplicadas à Neurologia, Neurocirurgia e Medicina Física e de Reabilitação, Faculdade de Engenharia da Universidade Católica Portuguesa, Oeiras, Portugal, July 2005.

Paulo Oliveira – "Tecnologias Aeroespaciais, Oceânicas e Ambiente", Dia de Reflexão Estratégica do DEEC, co-author com Prof. João Paulo Teixeira, Tagus Park, July 2005.

Carlos Silvestre – "Mission and Vehicle Control of Marine and Aerial Vehicles at Institute for Systems and Robotics", Computer Engineering Department University of California at Santa Cruz, California, USA, August 2005.

Agostinho Rosa – "Engenharia Biomédica", Instituto Nacional de Telecomunicações – INATEL, Santa Rita do Sapucaí, São Paulo, Brasil, October 2005.

A. Pedro Aguiar – "Performance Limitations in Reference-Tracking and Path-Following", Workshop on "New Developments in Control Performance Limitation Research: A Tale in the Network Age" held at CDC2005 - 44th IEEE Conference on Decision and Control, Seville, Spain, December 2005.

• Monthly seminars with Mathematic Department:

In a monthly basis and co-organized by João Xavier, the following seminars were held:

"Empirical model decomposition from a filter bank viewpoint"
Paulo Gonçalves, INRIA, Post-Doc ISR,
February 2005

"General inequalities for differentiable reproducing kernels"
Jorge Buescu, Prof. IST
February 2005

"Chirps everywhere"
Patrick Flandrin, INRIA
March 2005

"Os teoremas fundamentais do cálculo"
Jorge Buescu, Prof. IST
March 2005

"Local stationarity in passive detection of transient signals"
Francisco Garcia, Prof. IST
April 2005

"Grobner bases in geometry and robotics"
Carlos Fiorentino, Prof. IST
April 2005

"O M(in)istério da educação ou o problema da colocação dos docentes 2004/2005"
João Sobrinho, Prof. IST
May 2005

"To keep a secret – no secret with mathematics"
Joachim Erven, Prof. Fac. Munique
May 2005

"O jogo dos filósofos"
Jorge Nuno Silva, DM/UL
May 2005

"Manifold learning with tangent bundle approximation"
Jorge Silva, ISEL/ISR
May 2005

"Problema aerodinâmico de Newton e problema de transporte de massa"
Alexander Plakhov, UA
June 2005

"Some recent problems in stochastic optimal control"
Diogo Gomes, Prof. IST
June 2005

"Geometrical formulation of electromagnetism"
Marco Ribeiro, IT/IST
October 2005

"The strange world of partial differential equations"
Diogo Gomes, CAMGSD/IST
October 2005

"Optimality of idling policies"
Carlos Bispo, ISR/IST
November 2005

"Calculus of Variations and PDEs"
Diogo Gomes, CAMGSD/IST
November 2005

"Interconnection among ISPs in a competitive environment"
Alexandre Mateus, IN+/IST
December 2005

"Probability and PDEs"
Diogo Gomes, CAMGSD/IST

December 2005

• ISR Regular Seminars:

In a regular basis, and organized by Paulo Oliveira, the following seminars were held:

"From Discrete Specifications to Embedded Control Software"
Paulo Tabuada, University of Notre Dame, USA
January 2005

"Coordinated Path Following Under Communication Constraints – Part I"
Reza Ghabcheloo, Ph.D. Student, ISR / IST
February 2005

"AUV Terrain Aided Navigation using Particle Filters"
Francisco Curado, Ph.D. Student, ISR / IST
February 2005

"Projetos em Desenvolvimento no GATI – Grupo de Automação e Tecnologias da Informação"
Luiz Edival de Souza e Leonardo de Mello Honório, Universidade Federal de Itajubá, Brasil
February 2005

"Coordinated Path Following Under Communication Constraints – Part II"
Reza Ghabcheloo, Ph.D. Student, ISR / IST
March 2005

"The Fundamental Matrix for Dipotric Cameras with Radial Distortion. Application on the Calibration of Wide Area Camera Networks"
João Pedro Barreto, Faculdade de Ciências e Tecnologia, Universidade de Coimbra
March 2005

"Unmmaned Aerial Vehicles at Seville Universit"
Anibal Ollero, Seville University, Spain
March 2005

"Partition-Distance Methods for Image Segmentation"
Jaime Cardoso, INESC Porto
April 2005

"Guidance, Navigation and Control of Formation Flying Spacecraft Part I - Mission and GC Algorithm"
Dan Dumitriu and Pedro Lima, ISR / IST
April 2005

"Guidance, Navigation and Control of Formation Flying Spacecraft Part II - Navigation Algorithm"
Sónia Marques, Ph.D. Student, ISR / IST
May 2005

"Internet Trafic : Long Memory and multifractal? Application to anomaly detection"
Patrice Abry, CNRS, ENS-Lyon, France
May 2005

"R&D at IdMind – Engenharia de Sistemas, Lda "
João Cristóvão, IdMind
May 2005

"Know thy self. Modeling the basic cognitive properties of the immune system"
Jorge Carneiro, Instituto Gulbenkian de Ciência
June 2005

"Multivehicle Mapping in Large Environments"
José Neira, Departamento de Informática e Ingenieria de Sistemas, University of Zaragoza

June 2005

"An Information Theoretic Approach to the Fundamental Limitations of Feedback"
Nuno Martins, LIDS MIT
June 2005

"Compressed Domain Video Processing with Applications to Surveillance"
Miguel Tavares Coimbra, IEETA – Universidade de Aveiro
July 2005

"Sistemas Autónomos: Investigação em Curso no ISEP"
Eduardo Silva, LSA / ISEP
September 2005

"Positive 1D and 2D systems – realization problem"
Tadeusz Kaczorek, Warsaw University of Technology
September 2005

"Terrain Following Controller for Affne Parameter-Dependent Systems: An Application to Model-Scale Helicopters"
Nuno Paulino, M.Sc., ISR / IST
November 2005

"End-to-End Optimal Algorithms for Integrated QoS, Traffic Engineering, and Failure Recovery"
Constantino Lagoa, Associate Professor, Pennsylvania State University
November 2005

"On the Design of Optimal and Robust Supervisors for Deterministic Finite State Automata"
Constantino Lagoa, Associate Professor, Pennsylvania State University
December 2005

- **Some ISR Laboratories, such as Vislab and LaSEEB, organized internal weekly meetings.**

3.4.3 VISITS ABROAD

António Pascoal - Invited Scientist, National Institute of Oceanography, Dona Paula, Goa, India, in the scope of the MAYA-Sub project of the AdI and the joint Indian-Portuguese Cooperation Program, January 2005.

Luis Sebastião - Invited Researcher, National Institute of Oceanography, Dona Paula, Goa, India, in the scope of the MAYA-Sub project of the AdI and the joint Indian-Portuguese Cooperation Program, January 2005.

João Xavier – Australian National University, June 2005.

Agostinho Rosa – Escola Paulista de Medicina – Universidade Federal de São Paulo, São Paulo, Brasil, 2005.

Agostinho Rosa – INATEL – Santa Rita do Sapucai, Minas Gerais, Brasil, October 2005.

Agostinho Rosa – UNESP – Botucatu, São Paulo, Brasil, October 2005.

Sérgio M. Jesus - Heat, Light and Sound Research Inc., San Diego, USA, November 21 to December 22, 2005.

3.4.4 SUPERVISION OF STUDENTS ENROLLED IN FOREIGN UNIVERSITIES

Agostinho Rosa – Co–supervisor of Maria Cecília Lopes Conceição (Supervisor: Prof Dalva Poyares – UNIFESP), Ph.D. student, Departamento de Psicobiologia, Escola Paulista de Medicina, Universidade Federal de São Paulo, São Paulo, Brasil.

Alexandre Bernardino – Supervisor of Júlio Jesus León Pérez, Undergraduate Student at Universitat Jaume III, Castelló de la Plana, Spain.

António Pascoal – Co-advisor of Danilo de Carvalho, Ph.D. student enrolled at UFES (Federal University of Espírito Santo), Vitória, Espírito Santo, Brasil. Tema geral da tese de doutoramento: Path Following and Coordinated Path Following of Multiple Fully Actuated Marine Vehicles.

José A. Gaspar - Co-supervisor of Miguel Andrés Realpe Robalino, Undergraduate Student at Escuela Superior Politecnica del Litoral - ESPOL , Guayaquil, Ecuador.

José Santos-Victor - Co-supervisor of Roger Freitas, Ph.D. Student at Federal University of Espírito Santo, Vitória, Brasil.

José Santos-Victor - Co-supervisor of Sandra Nope, Ph.D. Student at University of Cali, Colombia.

Pedro Lima – Supervisor of Valdinei Silva, Ph.D. Student at Universidade Politécnica de São Paulo, Brasil – 12 months stay at ISR / IST, February 2005 to February 2006.

3.5 CONGRESS, MEETINGS AND PRESENTATIONS

This section includes invited talks, conferences attended and conferences where papers were presented, during 2005, by ISR-Lisbon researchers.

3.5.1 INVITED TALKS

Isabel Ribeiro – "Uma viagem ao mundo dos robots" – invited seminar integrated in the cycle Despertar para a Ciência – Beja, Portugal, organized by the Calouste Gulbenkian Foundation, the Portuguese Science and Technology Foundation and Governo Civil de Beja, Moura, Portugal, February 2005.

Pedro Lima – "Futebol Robótico – Porta para o Mundo da Ciência, Tecnologia e Inovação", Semana Informática do IST, Lisbon, Portugal, March 2005.

Isabel Ribeiro – "Uma viagem ao mundo dos robots" – invited seminar integrated in the cycle Despertar para a Ciência – Covilhã, Portugal, organized by the Calouste Gulbenkian Foundation, the Portuguese Science and Technology Foundation and the University of Beira Interior, Covilhã, March 2005.

António Pascoal - "Marine Robotics: Scientific and Technological Challenges", Invited Talk, Congress of the Sea, Nazaré, April 2005.

Pedro Lima – "Equipas de Robots Cooperantes", ROBÓTICA2005 – Invited Talk to ateliers session, April 2005.

António Pascoal - "Robotics for Ocean Exploration", Invited Talk, VII Summer Course of Ericeira, Instituto de Cultura Europeia e Atlântica (ICEA), Ericeira, Portugal, April 2005.

Isabel Ribeiro – "Uma viagem ao mundo dos robots" – invited seminar integrated in the cycle Despertar para a Ciência – Coimbra, Portugal, organized by the Calouste Gulbenkian Foundation, the Portuguese Science and Technology Foundation and the Institute of Interdisciplinary Research from University of Coimbra, Coimbra, Portugal, April 2005.

L.M.B.C. Campos – "Aeroacoustics research on the reduction of the environmental impact of aircraft noise", Keynote address, ICSV2005 – 12th International Congress of Sound and Vibration, Lisbon, Portugal, July 2005.

José Santos-Victor – "Robotic Vision: Biological Inspiration", Invited Talk, 20th Annual Meeting of the Federation of the Brazilian Societies of Experimental Biology, Águas de Lindóia, São Paulo, Brasil, August 2005.

António Pascoal - Theory and Practice of Marine Robotics in Portugal", Invited Talk, Research and Technology Initiatives in Portugal, CITAN, Portuguese Navy, September 2005.

António Pascoal - "Vehicle and Mission Control of Single and Multiple Autonomous Marine Robots", Invited Talk, UUV Showcase Conference, Southampton, UK, September 2005.

Carlos Silvestre – "Autonomous Helicopters for Inspection and Observation Tasks: the ALTICOPTER project", Workshop on the Employment of Unmanned Vehicles in the Naval Operations, Centro de Instrução de Táctica Naval (CITAN), Alfeite, Portugal, September 2005.

José Santos-Victor – "Human Activity Recognition from Video Sequences and the Neurophisiological Foundations for Gesture Recognition and Learning from Imitation", Invited Talk, CEDI – 1st Spanish Congress on Informatics, Spanish Network of Pattern Recognition and Applications, Granada, Spain, September 2005.

Alexandre Bernardino - "Robotic Vision: Applications to Humanoid Robots ", Invited Talk**,** X Simposio de Señales, Imagenes y Visión Artificial, Universidad del Valle, Cali, Colombia, September 2005.

Pedro Lima – "Robótica – Realidade e Ficção", 23º Encontro Juvenil de Ciência, organized by Associação Juvenil de Ciência, Lisbon, Portugal, September 2005.

Pedro Lima – "Research on Multi-Robot Systems at ISR / IST", Invited talk at LAAS - Laboratoire d'Analyse et d' Architecture des Systémes, Toulouse, France, September 2005.

Isabel Ribeiro – "Uma viagem ao mundo dos robots" – invited seminar integrated in the cycle Despertar para a Ciência – Vila Real, Portugal, organized by the Calouste Gulbenkian Foundation, the Portuguese Science and Technology Foundation and University of Trás-os-Montes e Alto Douro, Vila Real, Portugal, September 2005.

Alexandre Bernardino - "Visão Robótica @ VisLab-ISR : da Biologia à Engenharia", invited talk**,** 1ªs Jornadas de Engenharia Industrial, Instituto Politécnico de Castelo Branco, October 2005.

Pedro Lima - "RAPOSA - a Semi-Autonomous Robot for Rescue Operations", Invited Talk at Rescue Robotics Camp, University of Rome "La Sapienza", Italy, October 2005.

Isabel Ribeiro – "Uma viagem ao mundo dos robots" – invited seminar integrated in the cycle *Despertar para a Ciência* – Bragança, Portugal, organized by the Calouste Gulbenkian Foundation, the Portuguese Science and Technology Foundation and Escola Superior de Tecnologia e Gestão from Instituto Politécnico de Bragança, Bragança, Portugal, October 2005.

Agostinho Rosa – "Avanços no diagnóstico do sono: CAP", XIV Congresso Brasileiro do Sono – Associação Paulista de Medicina – São Paulo, Brasil, October 2005.

Pedro Lima – "Introdução à Robótica" – Cultural Nights at Students Residence Montes Claros, Lisbon, Portugal, November 2005.

Carlos Silvestre – "Mission and Vehicle Control of Marine and Aerial Vehicles", Keynote Speaker, MarTech05 - Primer Congreso Internacional de Tecnología Marina, organized by the Universidade Politécnica da Catalunha, Vilanova i la Geltrú – Vilanova, Catalonia, Spain, November 2005.

António Pascoal - "Vehicle and Mission Control of Single and Multiple Autonomous Marine Robots: The Present and a Vision of the Future", Plenary Talk, IWUR2005 - International Workshop on Underwater Robotics, Genova, Italy, November 2005.

António Pascoal - "Robots of the Abyss", Invited Talk, Festival of Science, School of Robotics, Genova, Italy, November 2005.

3.5.2 PARTICIPATIONS

- ICASSP2005 - IEEE International Conference on Acoustics, Speech, and Signal Processing, Philadelphia, March 2005.
- ROBÓTICA2005 – 5th Portuguese Robotics Festival, Coimbra, Portugal, April 2005.
- ICRA2005 - IEEE International Conference on Robotics and Automation, Barcelona, Spain, May 2005.
- APSS 2005 – Associated Professional Sleep Societies, 19th Annual Meeting, Denver, Colorado, USA, June 2005.
- IbPRIA2005 - 2nd Iberian Conference on Pattern Recognition and Image Analysis, Estoril, Portugal, June 2005.
- 16th IFAC World Congress, Prague, Czech Republic, July 2005.
- ICSV2005 – 12th International Congress of Sound and Vibration, Lisbon, Portugal, July 2005.
- ICAR2005 - 12th International Conference on Advanced Robotics, Seattle, Washington, USA, July 2005.
- Internoise, Rio de Janeiro, Brasil, August 2005.

- GN&C2005 - AIAA Guidance, Navigation, and Control Conference, San Francisco, USA, August 2005.
- BMVC2005 - British Machine Vision Conference, Oxford Brookes University, UK, September 2005.
- HAREM - International Workshop on Human Activity Recognition and Modelling (jointly with BMVC), Oxford, UK, September 2005.
- ICINCO2005 – 2nd International Conference on Informatics in Control, Automation and Robotics, Barcelona, Spain, September 2005.
- ICIP2005 - IEEE International Conference on Image Processing, Genova, Italy, September 2005.
- 4ªs Jornadas Portuguesas de Engenharia Costeira e Portuária, Angra do Heroísmo, Portugal, October 2005.
- XIV Congresso da Associação Paulista de Medicina, São Paulo, Brasil, October 2005.
- ESRS 2005 – 17th Congress of the European Sleep Research Society, Prague, Check Republic, October 2005.
- International Workshop on Underwater Robotics, Genova, Italy, 9-11 November, 2005.
- Brazilian Congress of Sleep, Curitiba, Brasil, November 2005.
- 36th International Symposium on Robotics, Tokyo, Japan, November 29 – December 1, 2005.
- CDC-ECC2005 - 44th IEEE Conference on Decision and Control/European Control Conference, Seville, Spain, December 2005.

3.6 SERVICE ACTIVITIES

This section is dedicated to service activities developed, during 2005, by ISR-Lisbon researchers as members of the national and international scientific community.

3.6.1 EDITORIAL BOARDS

Agostinho Rosa - Track Co-chair ACM SAC 05 – AI&CL Track, USA.

Agostinho Rosa – Member of the Editorial Board of the International Journal of Information & Communication Technology in Education.

Agostinho Rosa – Member of the Editorial Board of the International Journal of Web-based learning and Teaching Technologies.

Isabel Ribeiro – Member of the Editorial Board of the Robotics WEBook, an initiative developed under the framework of EURON.

José Santos-Victor – Associate Editor of the IEEE Transactions on Robotics.

L.M.B.C. Campos - Member of the Editorial Board of Progress of Aerospace Sciences.

L.M.B.C. Campos - Member of the Editorial Board of Integral Transforms and Special Functions.

Pedro Lima - Member of the Editorial Board of the Portuguese *Robótica* magazine.

Pedro Lima – Member of the Editorial Advisory Board of the Journal of Advanced Robotic Systems, published by ARS.

3.6.2 ADVISORY BOARDS

Agostinho Rosa – Member of Conselho das Comunidades Maceenses of APIM, Macau, RE-RP China.

Agostinho Rosa – Member of IFAC Technical Committee on Optimal Control.

Agostinho Rosa – Member of IASTED Technical Committee on Biomedical Engineering.

António Pascoal – Consultant, Program on Platforms for Marine Monitoring, Desk-Study, Marine Institute, Galway, Ireland.

António Pascoal – Portuguese Delegate to EurOcean: an Internet Portal for Marine Science and Technology in Europe, FCT, Lisbon, Portugal.

António Pascoal – Portuguese Delegate to the Marine Board of the European Science Foundation

António Pascoal – Member of the Consulting Committee of the Strategic Commission for the Oceans, in charge of submitting to the Adjunct Minister of the Prime Minister of Portugal an integrated document that is as a road map for future activities - at a national scale - on a wide range of ocean related issues, including marine science and technology.

António Pascoal – Portuguese Representative to EurOcean: an Internet Portal for Marine Science and Technology in Europe, FCT, Lisbon, Portugal.

José Santos-Victor - Member of the Aurora Board of Participants of the European Space Agency (ESA).

L.M.B.C. Campos - Member of the Advisory Board of Future Launchers Preparatory Board of European Space Agency (ESA).

Luis Custódio – Member of the Technical-Scientific Committee of the Portuguese Robotics Festival.

Pedro Lima – Trustee of the RoboCup Federation.

Pedro Lima - Member of the IFAC Technical Committee on Discrete Event and Hybrid Systems.

Pedro Lima – Founding member of the Technical-Scientific Committee of the Portuguese Robotics Festival.

Pedro Lima - Elected President of the IEEE Robotics and Automation Portugal Chapter, formed October 2005.

3.6.3 PROGRAMME AND TECHNICAL COMMITTEES

A. Pedro Aguiar – Member of International Federation of Automatic Control (IFAC), Technical Committee on Intelligent Autonomous Vehicles.

António Pascoal - Vice-Chair, International Federation of Automatic Control (IFAC), Technical Committee on Marine Applications.

António Pascoal - Member, International Federation of Automatic Control (IFAC), Technical Committee on Intelligent Autonomous Vehicles.

Agostinho Rosa- Member of the Programme Committtee of the MIC2005 – 24th IASTED Conference on Modeling, Identification and Control, Innsbruck, Austria, February 2005.

Agostinho Rosa – Member of the Programme Committee of the BioMed2005 – IASTED International Conference on Biomedical Engineering, Innsbruk, Austria, February 2005.

Agostinho Rosa – Member of the Programme Committee of the SAC2005 – 20th ACM Symposium on Applied Computing, Santa Fe, New Mexico, March 2005.

Agostinho Rosa – Member of the Programme Committee of the ICANNGA2005 – 7th International Conference on Adaptive and Natural Computing Algorithms , Coimbra, Portugal, March 2005.

Isabel Ribeiro – Member of the International Programme Committee of the ICRA2005 - Workshop on Cooperative Robotics, Barcelona, Spain, April 2005.

Pedro Lima – Co-Organizer (with Alessandro Saffiotti, Örebro University, Sweden) of the ICRA2005 - IEEE Workshop on Cooperative Robotics, Barcelona, Spain, April 2005.

Agostinho Rosa – Member of the Programme Committte of the ConfTele2005 – 5th Conference on Telecommunications, Tomar, Portugal, April 2005.

Paulo Oliveira - Member of the Programme Committee of the "Encontro Nacional de Robótica," Coimbra, April 2005.

José Santos-Victor - Member of the International Programme Committee of the ICRA2005 - IEEE International Conference on Robotics and Automation, , Barcelona, Spain, May 2005.

Agostinho Rosa – Member of the Programme Committee of the MICEIS2005 – 7th International Conference on Enterprise Information Systems**,** Miami, Florida, USA, May 2005.

Agostinho Rosa – Member of the Programme Technical Committee of the IRMA2005 – 16th IRMA International Conference, San Diego, California, USA, May 2005.

Jorge S. Marques – Member of the Program Committee of PRIS2005 - International Workshop on Pattern Recognition in Information Systems, Miami, USA, May 2005.

José Santos-Victor - Member of the International Programme Committee of the CVPR2005 - IEEE Computer Society Conference on Computer Vision and Pattern Recognition, San Diego, CA, June 2005.

João Sanches – Member of the Organizing Committee of IbPRIA2005 - Iberian Conference on Pattern Recognition and Image Analysis, Estoril, June 2005.

Agostinho Rosa – Member of the Programme Committee of the WSEAS Conferences, Lisboa, Portugal, June 2005.

António Pascoal – Member of the International Program Committee of the MED2005 - 13th IEEE Mediterranean Conference on Control and Automation, Cyprus, June 2005.

Pedro Lima – Member of the International Program Committee of the Poster Track of IJCAI2005 - International Joint Conference on Artificial Intelligence, Edinburgh, Scotland, 30 June – 5 August 2005.

Pedro Lima – Member of the International Program Committee of the RoboCup2005 Symposium, Osaka, Japan, July 2005.

Isabel Ribeiro – Chair of the IFAC Technical Committee on Intelligent Autonomous Vehicles (IAV), from July 2005 to July 2008. Vice-Chair of the same Technical Committee until July 2005.

Isabel Ribeiro – Member of the International Programme Committee of the ICAR2005 - 12th IEEE International Conference on Advanced Robotics, Seattle, Washington, USA, July 2005.

Pedro Lima – Senior PC member of the ICAR2005 – International Conference on Advanced Robotics, Seattle, Washington, USA, July 2005.

Isabel Ribeiro – Member of the International Programme Committee of the IFAC World Congress – 16th IFAC World Congress, Prague, Czech Republic, July 2005.

António Pascoal – Member of the International Program Committee of the IROS2005 - IEEE/RSJ International Conference on Intelligent Robots and Systems, Edmonton, Alberta, Canada, August 2005.

Isabel Ribeiro – Member of the International Programme Committee of the ETFA2005 - 10th IEEE International Conference on Emerging Technologies and Factory Automation, Catania, Italy, September 2005.

Luis Custódio - Member of the International Program Committee of the Intelligent Robots & Systems Track, in the frame of ETFA2005 - 10th IEEE Conference on Emerging Technologies and Factory Automation, Catani, Italy, September 2005.

José Santos-Victor - Chair, HAREM2005 - International Workshop on Human Activity Recognition and Modeling, Oxford, UK, September 2005.

Jorge S. Marques – Member of the International Program Committee of HAREM2005 – International Workshop on Human Activity Recognition and Modeling, Oxford, UK, September 2005.

Isabel Ribeiro – Member of the International Programme Committee of the ICINCO2005 – 2nd International Conference on Informatics in Control, Automation and Robotics, Barcelona, Spain, September 2005.

Luis Custódio - Member of the International Program Committee of the ICINCO2005 - 2nd International Conference on Informatics in Control, Automation and Robotics, Barcelona, Spain, September 2005.

Agostinho Rosa – Member of the International Programme Committee of the ICINCO2005 – 2nd International Conference on Informatics in Control, Automation and Robotics, Barcelona, Spain, September 2005.

Luis Custódio - Member of the International Program Committee of the MARS2005 - 1st International Workshop on Multi-Agent Robotic Systems, Barcelona, Spain, September 2005.

Agostinho Rosa – Member of the Programme Committee of the ICCB2005 – 2nd International Conference on Computational Bioengineering, Instituto Superior Técnico, Lisbon, Portugal, September, 2005.

Agostinho Rosa – Member of the Programme Committee of the BioMech2005 – 3rd IASTED International Conference on Biomechanics, Benidorm, Spain, September 2005.

Agostinho Rosa - Member of the Programme Committee of the BIC05 – International Symposium on Bio-Inspired Computing, Prunet, Malasya, September 2005.

Pedro M. Q. Aguiar – Member of the Technical Committee of the ICIP2005 - IEEE International Conference on Image Processing, Genova, Italy, September 2005.

José Santos-Victor - Member of the International Programme Committee of the VS-PETS2005 - 7th IEEE International Workshop on Performance Evaluation of Tracking and Surveillance, Beijing, China, October 2005.

António Pascoal – Member of the International Program Committee of the International Workshop on Underwater Robotics for Sustainable Management of Marine Ecosystems and Environmental Monitoring, Genova, Italy, November 2005.

Luís Custódio – Member of the International Program Committee of JETC05 – 3as Jornadas de Electrónica, Telecomunicações e de Computadores do ISEL, Lisbon, Portugal, November 2005.

Pedro Lima - Member of the International Program Committee of the IROBOT2005 - 1st Workshop on Intelligent Robotics, in the frame of EPIA2005 - 12th Portuguese Conference on Artificial Intelligence, Covilhã, Portugal, December 2005.

Isabel Ribeiro – Member of the International Programme Committee of the CDC-ECC2005 - Joint 44th IEEE Conference on Decision and Control and European Control Conference, Seville, Spain, December 2005.

Isabel Ribeiro – Member of the Programme Committee of the IROBOT2005 - 1st Workshop on Intelligent Robotics, in the frame of the 12ª Conferência Portuguesa de Inteligência Articial, Covilhã, Portugal, December 2005.

Agostinho Rosa – Member of the Programme Committee of the ALEA2005 – 2nd Portuguese Workshop on Artificial Life and Evolutionary Algorithms, Covilhã, Portugal, December 2005.

Isabel Lourtie – Associate member of the IEEE Sensor Array and Multichannel Technical Committee.

3.6.4 CHAIRPERSON

L. M. B. C. Campos - Chairman of Symposium on "Advanced sensor payloads for Unmaned Air Vehicles (UAVs)", Sensors and Electronics Panel, Research and Technology Organization, Lisbon, Portugal, 2-3 May 2005.

Isabel Ribeiro – Chair of the session "Mobile Robotics" on the 16th IFAC World Congress, Prague, Czech Republic, July 2005.

António Pascoal – Chair of the session "Multiple Vehicles II", on the 16th IFAC World Congress, Prague, Czech Republic, July 2005.

Carlos Silvestre – Chair of the session "Intelligent Vehicle Control", on the 16th IFAC World Congress 2005, Prague, Czech Republic, June 2005.

L. M. B. C. Campos - Chairman of Aeroacoustics Session on ICSV2005 – 12th International Congress of Sound and Vibration, Lisbon, Portugal, 11-14 July 2005.

António Pascoal – Chair of the session "Cooperation and Control I", on the IWUR2005 - International Workshop on Underwater Robotics, Genova, Italy, November 2005.

António Pascoal – Chair of the session "Control of Mechanical Systems I", on the CDC-ECC2005 - IEEE Control and Decison Conference / European Control Conference, Seville, Spain, December 2005.

Paulo Oliveira – Chair of the session "Aerospace and Vehicle Control", on the CDC-ECC2005 - IEEE Control and Decision Conference / European Control Conference, Seville, Spain, December 2005.

3.6.5 REVIEWERS

Agostinho Rosa - Journal of Sleep Research.

Agostinho Rosa - IEEE Transaction of Biomedical Engineering.

Agostinho Rosa – Clinical Neurophysiology.

Agostinho Rosa – Sleep.

Agostinho Rosa – Sleep Medicine.

Agostinho Rosa – Journal of Heuristics.

Agostinho Rosa – Pattern Recognition Letters.

Alexandre Bernardino – IJHR – International Journal of Humanoid Robotics.

Alexandre Bernardino – BMVC2005 - British Machine Vision Conference.

Alexandre Bernardino – IBPRIA2005 - 2nd Iberian Conference on Pattern Recognition and Image Analysis.

Alexandre Bernardino – ICRA2005 - IEEE International Conference on Robotics and Automation.

Alexandre Bernardino – IROS2005 - IEEE / RSJ International Conference on Intelligent Robots and Systems.

Alexandre Bernardino - ICDL2006 - 5th International Conference on Development and Learning.

Alexandre Bernardino – HAREM2005 – Wrkshop on Human Activity Recognition and Modelling.

Alexandre Bernardino – EPIROB2005 – Epigenetic Robotics Workshop.

António Pascoal – International Journal of Systems Science.

António Pascoal – Journal of Applied Mathematics.

António Pascoal – IEEE Transactions on Automatic Control.

António Pascoal – Journal of Guidance, Control, and Dynamics

António Pascoal – Automatica

António Pascoal – IEEE Transactions on Control Systems Technology.

António Pascoal – ACC2005 – American Control Conference.

António Pascoal – CDC2005 – 44th IEEE Conference on Decision and Control.

António Pascoal – ICTA2005 - 5th International Conference on Technology and Automation.

António Pascoal – 16TH IFAC World Congress.

António Pascoal – IROS2005 - IEEE / RSJ International Conference on Intelligent Robots and Systems.

António Pascoal – MED2005 – Mediterranean Control Conference.

A. Pedro Aguiar – IEEE Transactions on Automatic Control.

A. Pedro Aguiar – IEEE Transactions on Robotics.

A. Pedro Aguiar – Automatica.

A. Pedro Aguiar – CDC-ECC2005 – 44th IEEE Control and Decision Conference/European Control Conference.

A. Pedro Aguiar – ACC2005 – American Control Conference.

A. Pedro Aguiar – 16th IFAC World Congress.

A. Pedro Aguiar – ASME International Mechanical Engineering Congress and Exposition.

Carlos Silvestre - IEEE Robotics and Automation Magazine, Institute of Electrical and Electronic Engineers.

Carlos Silvestre - IEEE Transactions on Control Systems Technology.

Carlos Silvestre - International Jornal of Systems Science.

Carlos Silvestre - ACC2005 - American Control Conference.

Carlos Silvestre – CDC-ECC2005 - 44th IEEE Conference on Decision and Control Conference/European Control Conference.

Carlos Silvestre – ICRA2005 **-** International Conference on Robotics and Automation.

Carlos Silvestre - 16TH IFAC World Congress.

Carlos Silvestre – IROS2005 - IEEE/RSJ International Conference on Intelligent Robots and Systems.

Carlos Silvestre – ISIC2005 - International Symposium on Intelligent Control held at MED2005.

Francisco Garcia - IEEE Transactions on Circuits and Systems.

Isabel Ribeiro – Co-coordinator and reviewer of the PhD grant evaluation process by FCT.

Isabel Ribeiro – IEEE Transactions on Robotics and Automation.

Isabel Ribeiro – ICINCO2005 - 2nd International Conference on Informatics, Control, Automation and Robotics.

Isabel Ribeiro – ETFA2005 – 10th IEEE International Conference on Emerging Technologies and Factory Automation.

Isabel Ribeiro – CDC-ECC2005 – Joint 44th IEEE Conference on Decision and Control and European Control Conference.

Isabel Ribeiro – ICRA2005 - Workshop on Cooperative Robotics.

Isabel Ribeiro – ICAR2005 – 12th IEEE International Conference on Adavnced Robotics.

João Gomes - IEEE Journal of Oceanic Engineering.

João Gomes - IEEE Electronics Letters.

João Sequeira – ICINCO2005 - 2nd International Conference on Informatics, Control, Automation and Robotics.

João Sequeira – ICRA2005 – IEEE International Conference on Robotics and Automation.

João Sequeira – ROBÓTICA2005 – 5th Portuguese Robotics Festival.

João Sequeira – Scientia Iranica Journal.

João Xavier - IEEE Transactions on Signal Processing.

Jorge S. Marques – ECCV2006 – 9th European Conference on Computer Vision.

Jorge S. Marques – ICTA2005 - International Conference on Technology and Automation.

José A. Gaspar – BMVC2005 - British Machine Vision Conference.

José A. Gaspar – IBPRIA2005 - 2nd Iberian Conference on Pattern Recognition and Image Analysis.

José A. Gaspar - ICRA2005 - IEEE International Conference on Robotics and Automation.

José A. Gaspar – IROS2005 - IEEE / RSJ International Conference on Intelligent Robots and Systems.

José Santos-Victor – IEEE Transactions on Pattern analysis and Machine Intelligence.

José Santos-Victor - IEEE Transactions on Robotics and Automation.

José Santos-Victor - IEEE Transactions on Biomedical Engineering.

José Santos-Victor - IEEE Transactions on Robotics.

José Santos-Victor - IEEE Transactions on System Man and Cybernetics.

José Santos-Victor - Journal of Robotics and Autonomous Systems.

José Santos-Victor - BMVC2005 - British Machine Vision Conference.

José Santos-Victor - IbPRIA2005 - 2nd Iberian Conference on Pattern Recognition and Image Analysis.

José Santos-Victor - ICRA2005 - IEEE International Conference on Robotics and Automation.

José Santos-Victor – IROS2005 - IEEE / RSJ International Conference on Intelligent Robots and Systems.

L.M.B.C. Campos - Journal of Sound and Vibration.

L.M.B.C. Campos - Journal of Fluid Mechanics.

Luis Custódio - RoboCup2005 Symposium.

Luis Custódio – IJCAI2005 – 19th International Joint Conference on Artificial Intelligence.

Luis Custódio - IEEE Transactions on Fuzzy Systems.

Margarida Silveira - IbPRIA2005 - Iberian Conference on Pattern Recognition and Image Analysis.

Paulo Oliveira – CDC-ECC2005 – 44th IEEE Control and Decision Conference / European Control Conference.

Paulo Oliveira – IbPRIA2005 - Iberian Conference on Pattern Recognition and Image Analysis.

Paulo Oliveira – 16th IFAC World Congress.

Paulo Oliveira – Encontro Nacional de Robótica.

Paulo Oliveira - IEEE Transactions on Oceanic Engineering.

Pedro M. Q. Aguiar – IEEE Transactions on Image Processing.

Pedro M. Q. Aguiar – ICIP2005 - IEEE International Conference on Image Processing.

Pedro Lima - IEEE Transactions on Robotics.

Pedro Lima - IEEE Robotics and Automation Magazine.

Pedro Lima - IEEE Transactions on Systems, Man and Cybernetics – Part B.

Pedro Lima - IEEE Proceedings on Control Theory and Applications.

Pedro Lima - ICRA2006 - IEEE International Conference on Robotics and Automation.

Pedro Lima – IROS2006 – IEEE / RSJ International Conference on Intelligent Robots and Systems.

Pedro Lima – IAS9 - 9th Conference on Intelligent Autonomous Systems Conference.

Pedro Lima - IROBOT2005 - 1st Workshop on Intelligent Robotics, in the frame of EPIA2005 – 12th Portuguese Conference on Artificial Intelligence.

Pedro Lima - IJCAI2005 – 19th International Joint Conference on Artificial Intelligence.

Pedro Lima - RoboCup2005 Symposium.

Sérgio M. Jesus – Journal of Acoustical Society of America.

Sérgio M. Jesus – IEEE Transactions on Signal Processing.

Sérgio M. Jesus - ICASSP 2005 - IEEE International Conference on Acoustics, Speech and Signal Processing.

3.6.6 OTHER ACTIVITIES

Agostinho Rosa – Presidente do Conselho Fiscal da Associação Portuguesa de Sono (APS).

António Pascoal – Member of the Workgroup on "Research Vessels" of the Intersectorial Oceanographic Mission / Ministry of Science and Technology, Portugal. Objective of the Workgroup: to assess the state of the scientific fleet and to define guidelines for its expansion and efficient utilization by the scientific community at large.

António Pascoal – Member of the Workgroup on "Deep Sea Research" of the Intersectorial Oceanographic Mission / FCT, Portugal. Objective of the Workgroup: to foster the development of deep sea marine science and technologies.

António Pascoal – Member of the SCOR (Scientific Committee on Ocean Research) Panel on New Technologies for Observing Marine Life, the Sloan Foundation, USA.

António Pascoal – Member of the Global Ocean Observation System (GOOS) Working Group, Intersectorial Oceanographic Comission, FCT, Lisbon, Portugal.

A. Pedro Aguiar - Organizer of the workshop on "New Developments in Control Performance Limitation Research: A Tale in the Network Age'" for the CDC2005 – 44th IEEE Conference on Decision and Control, Seville, Spain, December 2005 (with Jie Chen, Rick Middleton, and Li Qiu).

Isabel Lourtie – Responsible for the Signal and Systems group of disciplines of the Systems, Decision and Control scientific area of IST's Department of Electrical and Computer Engineering.

Isabel Lourtie - IST's Department of Electrical and Computer Engineering representative at IST´s Pedagogic Board.

Isabel Ribeiro – Adjoin-Director for Project Management of Instituto Superior Técnico.

Isabel Ribeiro – Member of the jury of the 5th Portuguese Robotics Festival, Coimbra, Portugal, April 2005.

João Gomes - Systems manager of ISR signal processing laboratory.

João Silva Sequeira – Coordinator of Specialisation Area in Systems, Decision and Control of the Electrical and Computer Engineering Programme - IST's Dept. of Electrical and Computer Engineering.

Jorge S. Marques – Coordinator of the Post-Graduation Program (M.Sc.,Ph.D) in Electrical and Computer Engineering, Instituto Superior Técnico.

L.M.B.C. Campos – Coordinator of IST's Secção de Mecânica Aeroespacial.

Paulo Oliveira - Member of the Jury to select the Portuguese representatives for the Schneider Electric Expo Inici@tive 2005, Seville, Spain, May 2005.

Pedro Lima – Reviewer of Ph.D. Thesis of Jérémi Gancet, "Systèmes Multi-Robots Aériens: Architecture pour la Planification, la Supervision et la Coopération", Institut National Polytechnique de Toulouse, France, April 2005.

Pedro Lima – Evaluator of research project proposals submitted to the 4th Call of the FP6 of the European Commission, Information Society Technologies (IST-2.4.8. Cognitive Systems), Brussels, Belgium, April 2005.

Pedro Lima – Evaluator of research project proposal submitted to the Austrian Science Fund, June 2005.

Pedro Lima – Evaluator of research project proposal submitted to the Dutch Technology Foundation STW, December 2005.

Pedro Lima – Member of the Post-Graduation on Electrical and Computers Engineering Coordination Committee at IST.

Victor Barroso – Vice Presidente of IST's Scientific Council.

Victor Barroso - Coordinator of the Scientific Area of Telecommunications in IST's Dept. of Electrical and Computer Engineering.

3.7 ACADEMIC ACTIVITIES

Here we list the participation, during 2005, of ISR-Lisbon researchers in committees for Doctoral and Master thesis, and other academic related activities.

João Silva Sequeira – Member of the M.Sc. Thesis Committee of Isabel Cristina da Silva Barros Rodrigues Mendes Pinto, "Representações Dinâmicas para a Geração de Comportamento Predictivo em Sistemas Duo-Agente Cooperativos", University of Minho, January 2005.

Isabel Ribeiro – Member of the M.Sc. Thesis Committee of José Inácio Rocha, "Inspecção e Manutenção Robótica em Linhas de Transporte de Energia Eléctrica de Alta Tensão", Instituto Superior Técnico, September 2005.

Isabel Ribeiro – Referee of the Ph.D. Thesis Committee (but not present at the exam) of Diego Ortin Trasobares "Automated model acquisition using laser and vision", University of Zaragoza, Spain, March 2005.

Isabel Ribeiro – Member of the Ph.D Thesis Committee of Alberto Manuel Martinho Vale, "Mobile Robot Navigation in Outdoor Environments: A Topological Approach", Instituto Superior Técnico, June 2005.

João Sentieiro – Member of the Ph.D. Thesis Committee of Fernando Manuel Fernandes Melício, "Horários Escolares por Simulated Annealing", Instituto Superior Técnico, December 2005.

João Silva Sequeira – Member of the M.Sc. Thesis Committee of José Inácio Rocha, "Inspecção e Manutenção Robótica em Linhas de Transporte de Energia Eléctrica de Alta Tensão", Instituto Superior Técnico, September 2005.

Luís Custódio – Member of the M.Sc. Thesis Committee of Vasco Miguel Yones Coutinho Pires, "Sistema de Decisão Distribuído Baseado em Lógica para uma Equipa Multi-Robot", Instituto Superior Técnico, Universidade Técnica de Lisboa, July 2005.

Luís Custódio – Member of the Ph.D. Thesis Committee of Luís Filipe Graça Morgado, "Integração de Emoção e Raciocínio em Agentes Inteligentes", Faculdade de Ciências, Universidade de Lisboa, December 2005.

Luís Custódio – Member of the Ph.D. Thesis Committee of Fernando Manuel Fernandes Melício, "Horários Escolares por Simulated Annealing", Instituto Superior Técnico, December 2005.

Pedro Lima – Advisor of the Post-Doctoral Student Dan Dumitriu.

Pedro Lima – Member of the Ph.D. Thesis Committee of Alberto Vale, "Mobile Robot Navigation in Outdoor Environments: a Topological Approach", Instituto Superior Técnico, Universidade Técnica de Lisboa, June 2005.

Pedro Lima – Member of the M.Sc. Thesis Committee of Abel Borges Ferreira Mendes, "Detecção e Seguimento de Alvos com Laser Range Finder", Faculdade de Ciências e Tecnologia, Universidade de Coimbra, 2005.

Pedro Lima – Member of the M.Sc. Thesis Committee of Vasco Miguel Yones Coutinho Pires, "Sistema de Decisão Distribuído Baseado em Lógica para uma Equipa Multi-Robot", Instituto Superior Técnico, Universidade Técnica de Lisboa, July 2005.

Pedro Lima – Member of the M.Sc. Thesis Committee of Pedro Figueiredo Santana, "Survival Kit: A Bottom Layer for Robot Navigation", Departamento de Informática, Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia, November 2005.

José Santos-Victor – Member of the Ph.D. Thesis Committee of Diego Ortín Trasobares, "Automated model acquisition using laser and vision", Department of Informática e Ingeniería de Sistemas, University of Zaragoza, Spain, June 2005.

José Santos-Victor – Member of the Ph.D. Thesis Committee of Jaume Vergès, "Color Constancy and Image Segmntation Techniques for Application to Mobile Robotics", Department of Enginyeria de Sistemas, Automàtica I Informàtica Industrial,Universidad Politecnica de Catalunya, Spain, July 2005.

José Santos-Victor – Member of the Ph.D. Thesis Committee of Paulo Jorge Sequeira Gonçalves, "Controlo Visual de Robots Manipuladores", Department of Mechanical Engineering, IST, April 2005.

José Santos-Victor – Member of the M.Sc. Thesis of Ricardo Marranita, "Visual Tracking of Articulated Objects: an application to the Human Hand", Instituto Superior Técnico, November 2005 (Supervisor).

Alexandre Bernardino – Member of the M.Sc. Thesis Committee of Ricardo Marranita, "Visual Tracking of Articulated Objects: an application to the Human Hand", Instituto Superior Técnico, November 2005.

Alexandre Bernardino – Evaluator of the Ph.D. proposal, "Una Arquitectura de Control Basada en el Aprendizaje por Imitación de Gestos Aplicada en Robótica", Sandra Esperanza Nope Rodriguez, Universidad del Valle, Cali, Colombia.

Sérgio M. Jesus - Member of the Ph.D. Thesis Committee of Damien Gaucher, "Étude des potentialités de la Tomographie Acoustique Oceanique Passive", Université de Bretagne Occidentale (UBO), Brest, France, January 2005.

Sérgio M. Jesus – Member of the Ph.D. Thesis Committee of Paulo Felisberto, "Data Fusion Applied to Ocean Acoustic Tomography", University of Algarve, Portugal, April 2005.

Orlando Rodriguez – Member of the Ph.D. Thesis Committee of Paulo Felisberto, "Data Fusion Applied to Ocean Acoustic Tomography", University of Algarve, Portugal, April 2005.

Agostinho Rosa – Member of the M.Sc. Thesis Committee of Nelson Ricardo Perdigão Pereira, "Algoritmo Evolutivo Híbrido – alinhamento Múltiplo de Sequências", IST, December 2005.

Agostinho Rosa – Member of the Ph.D. Thesis Committee of Fernando Manuel Fernandes Melício, "Horários Escolares por Simulated Annealing", Instituto Superior Técnico, December 2005.

Paulo J. S. Gil – Member of the Ph.D. Thesis Committee of Olga V. Joukova, "Alguns problemas de estabilização passiva de satélites", Universidade da Beira Interior, 2005.

Paulo J. S. Gil – Member of the Ph.D. Thesis Committee of Elena N. K. Duarte, "Aerodynamic stabilization of LEO satellites, general theory", Universidade da Beira Interior, 2005.

Jorge S. Marques – Member of the Ph.D. Thesis Committee of José Silvestre da Serra Silva, "Segmentação Pulmonar em Estudos de Tomografia Axial Computorizada", Universidade de Aveiro, 2005.

Jorge S. Marques – Member of the Ph.D. Thesis Committee of Vitorino Ramos, "Padrões de Autoganização", Instituto Superior Técnico, 2005.

Jorge S. Marques – Member of the M.Sc. Thesis Committee of André Lourenço, "Unsupervised Learning Methods and Combination Strategies", Instituto Superior Técnico, 2005.

Jorge S. Marques – Member of the M.Sc. Thesis Committee of Pedro Carlos da Silva Santos, "A 2D to 3D Geometric Interpolation Algorithm for Marker-Based Single-Camera Tracking", Instituto Superior Técnico, 2005.

João Xavier – Member of the Ph.D. Thesis Committee of Mário Pedro Silva, "Emergent Radio Systems", Instituto Superior Técnico, 2005.

João Xavier – Member of the M.Sc. Thesis Committee of Marco Ribeiro, "Formulação Geométrica do Electromagnetismo", Instituto Superior Técnico, 2005.

Pedro M. Q. Aguiar – Member of the M.Sc. Thesis Committee of R. Santos, "Transmissão de Video em Tempo Real na Internet", Universidade de Aveiro, 2005.

Pedro M. Q. Aguiar – Member of the M.Sc. Thesis Committee of Nuno Silva, "Global Image Registration", Instituto Superior Técnico, Universidade Técnica de Lisboa, 2005.

Carlos Bispo – Member of the Ph.D. Thesis Committee of Nelson Fernando Chibeles Pereira Martins, "Modelação e Optimização de Sistemas de Patrulha", Instituto Superior Técnico, Universidade Técnica de Lisboa, 2005.

João Gomes – Co-advisor and Member of the Ph.D. Thesis Committee of António João Freitas G. da Silva, "Time-reversed underwater communications", Instituto Superior Técnico, 2005.

Carlos Silvestre – Member of the M.Sc. Thesis Committee of Nuno Paulino "Terrain Tracking Control Strategies for Autonomous Vehicles with application to Unmanned Helicopters", Instituto Superior Técnico, Universidade Técnica de Lisboa, June 2005.

Paulo Oliveira – Member of the M.Sc. Thesis Committee of Carlos Bastos, "Controlo de uma Aeronave Robotizada no Solo", Instituto Superior Técnico, Universidade Técnica de Lisboa, June 2005.

António Pascoal - Member of the Ph.D. Thesis Committee of Paulo Alexandre da Silva Felisberto, "Data Assimiliation with Applications to Ocean Acoustic Tomography," University of the Algarve, February 2005.

3.8 VISITS TO ISR

3.8.1 Distinguished Visitors

- **Prof. Giulio Sandini** - DIST, University of Genova, Italy.
- **Prof**. **Aude Billard,** EPFL, Switzerland.
- **Prof**. **Auke Ijspeert,** EPFL, Switzerland.
- **Prof. Claes von Hofsten**, University of Uppsala, Sweden.
- **Prof. Kerstin Dautenhaun,** University of Hertfordshire, United Kingdom.
- Visit of some of the participants of the Seminar on Scientific and Technological Policies and Funding Mechanisms to Cooperation, organized by GRICES (from the Ministry of Science, Technology and Universities) in the frame of CPLP, October 2005.
- Visit of a delegation of the Atlantech (Atlantic Network for Business Innovation and Technology Transfer) that were seeking for opportunities for technology transfer in Europe.
- Visit of delegation from China.
- Under the Indo-Portuguese Cooperation Program in Science & Technology, and in the context of the bi-lateral project on the Development of a small Autonomous Underwater Vehicle within that program, the following four scientists:

  R. Madan
  E. Desa
  P. Maurya
  G. Navelkar

  with the Marine instrumentation Division of the National Institute of Oceanography (NIO), Dona Paula, Goa, India visited the Institute of Systems and Robotics (ISR) for a *period of 18 days, during the year of 2005*. This was the third formal visit from NIO scientists under the Indo-Portuguese S&T program sponsored by GRICES Portugal The objectives of the visit were to:

1) Exchange notes and design ideas on the mechanical and electrical hardware of the two small AUVs under development at NIO and IST/ISR in the scope of the MAYA-PT project of the AdI and the MAYA-IN project of the Indian Ministry for Ocean Development.

2) To discuss topics related to the design and implementation of the systems for vehicle navigation, guidance, and control.

3) To prepare a series of tests that will take place in Goa, India, in February-March 2006.

- **Prof. Constantino Lagoa,** Pennsylvania State University, USA, from October-December 2005, during his sabbatical leave. He did research on System Identification and Nonlinear Control.

3.8.2 Other Visits

As part of the activities of scientific dissemination and with the aim of showing to young scholars real applications of science and technology, ISR/IST received the visits from a number of High-School herein listed:

- High-School Emídio Navarro, Viseu, January 2005 – 40 students.
- High-School António Arroio, Lisbon. January 2005 – 20 students.
- Professional School Gustavo Eiffel, Amadora, February 2005 - 15 students.
- High-School Daniel Sampaio, Sobreda. February 2005 - 6 students.
- High School from Amadora, February 2005, 70 students.
- High School of Lagos, March 2005.
- Basic School São João de Deus, Montemor-o-Novo, April 2005 – 30 students.
- Professional School of Telheiras, June 2005 - 30 students.
- Professional and Technological School of Zona do Pinhal - Pedrogão Grande, November 2005 – 30 students.

3.9 SPECIAL EVENTS

3.9.1 ROBOTCUB Meeting/Workshop

Estoril, Portugal
17-19 March 2005

Organizers: Prof. José Santos Victor, Prof. Alexandre Bernardino.
Laboratories: Vislab – Computer Vision Lab.
Description: The first meeting of the RobotCub consortium held outside Italy was hosted by IST and held in Estoril, Portugal, in April 2005. The meeting consisted of a two-day workshop with about 50 participants, in addition to the project management meeting. The workshop included presentations from some of the partners in the consortium and invited speakers. The topics covered humanoid robot design, cognition, sensory-motor coordination, developmental psychology and robotic imitation, among others. A visit was organized to the ISR and IST.
URL: http://www.isr.ist.utl.pt/~jasv/harem2005/

3.9.2 IEEE ICRA 2005 Workshop on Cooperative Robotics

Barcelona, Spain
April, 2005

Chairs: Prof. Pedro Lima, Prof. Alessandro Saffiotti, Örebro University, Sweden.
Laboratories: Intelligent Systems Laboratory.
Description: The domain of cooperative robotics is acquiring prominent importance in many key application areas. Teams of robots cooperatings among them and/or with humans can perform a variety of tasks in a faster, more reliable, and more flexible way than a single robot. The rapidly growing scientific and industrial interest in cooperative robotics makes this domain extremely important for graduate students and young researchers in the field of autonomous robotics. This workshop had four primary aims. First, to expose international researchers in general, and graduate students in particular, to the latest technologies for cooperative robotics. Second, to help young researchers and students to create an international network of contacts. Third, to consolidate the research community in this field, which is still somehow dispersed, especially in Europe. Fourth, to enhance the visibility of European research on cooperative robotics. The workshop had two invited speakers (Marco Dorigo and Gaurav Sukhatme) and 7 papers presented by student authors, out of the 14 submitted and reviewed by an international committee composed of senior researchers.

3.9.3 IbPRIA 2005 - Iberian Conference on Pattern Recognition and Image Analysis

Estoril, Portugal
7-9 June, 2005

General Chairs: Jorge S. Marques, Nicolás Perez de la Blanca.
Laboratories: Signal and Image Processing Group.
Support: International Association for Pattern Recognition (IAPR), Portuguese and Spanish Associations for Pattern Recognition (APRP, AERFAI).
Description: IbPRIA 05 was the second of this series of international conferences and was organized for the first time in Portugal. The conference had 180 researchers from 38 countries working in the areas of Pattern Recognition and Image Analysis. The conference was organized in a single track format with 30 oral presentations and 141 poster presentations and three invited speakers: Profs. David Lowe (British Columbia Univ), Wiro Niessen (Utrecht Univ.) and Isidore Rigoutsos (IBM). The proceedings were published by Springer Verlag in LNCS series (vol. 3522, 3523).

URL: http://ibpria2005.isr.ist.utl.pt

3.9.4. "Construction of a Soccer Robot" – Short Course for High-school Students

Lisbon, Portugal
18-22 July, 2005

Program: Ocupação Científica de Jovens nas Férias 2005.
Coordinator: Prof. Pedro Lima.
Laboratories: Intelligent Systems Laboratory.
Support: National Agency for the Scientific and Technological Cultures – Ciência Viva.
Description: This was a workshop for High School students aiming at motivating them for the learning of Science and Technology, namely Robotics. The students had to build from an initial kit a team of two robots capable of playing football according to the rules of RoboCup Junior. In the process, they learned from several disciplines such as math, electronics, programming and mechanics, among others. In the end, the available teams played in a round-robin tournament. The workshop had the participation of 31 students from 25 schools, selected out of 44 candidates.
URL: http://lci.isr.ist.utl.pt/projects/educational/cvnasferias/index2005.html

3.9.5. HAREM 2005 – Workshop on Human Activity Recognition and Modelling

Oxford, UK
September 9th, 2005

Chair: Prof. José Santos Victor.
Laboratories: Vislab - Computer Vision Lab.
Description: The first International Worksho on Human Activity Recognition and Modelling was organized jointly with the British Machine Vision Conference, at Oxford Brookes university, Oxford, UK.
The call for papers elicited the submission of 25 high quality manuscripts from all over the world, exceeding our expectations for a one day workshop. The Program Committee carried out the thorough task of assessing the papers technical quality and their suitability for presentation at the workshop. A total of 13 papers were accepted for presentation, covering multiple domains related to Human Activity Recognition and Modeling and providing a unified vision of the state of the art and current challenges.
URL: http://www.isr.ist.utl.pt/~jasv/harem2005/

3.9.6. Field experiment: participation in the Makai Ex Sea Trial

Hawaii, USA
September 10 – October 2, 2005

Participation in the Makai Ex sea trial, organized by the HLS Research, San Diego (USA), off the west coast of the Island of Kauai, Hawaii, USA. This participation was made under the High Frequency Initiative collaboration involving SiPLAB-UALG(P), NURC(NATO-I), NRL (USA), SPAWAR (USA), WHOI (USA), MPL (USA) and SAIC (USA).

3.9.7. “Day of Space” and “Second Forum for Space”

Knowledge Pavillion, Lisbon
26th November, 2005

ISR/IST participated in the event “Day of Space” and in the “Second Forum for Space”, organized by GRICES (The Department for International Relationships of the Ministry for Science and Technology). ISR/IST had a stand where some posters and robotic prototypes were displayed.

3.10 AWARDS

Maria Cecília Lopes Conceição – Prémio de Melhor Jovem Investigadora em Pediatria – Associação Americana da Medicina do Sono, 2005.

Raquel César – Prémio de Melhor Artigo no World Scientific and Engineering Academy and Society, September 2005.

B. Pires and P. Aguiar, "Featureless Global Alignment of Multiple Images", ICIP2005, rated by the IEEE ICIP Technical Committee among the top 10 % of the accepted papers.

Luís Vidigal prize for the two best graduation project on Electrical and Computer Engineering (ex aequo):

Bernardo Esteves Pires – "Imagens Panorâmicas", supervised by Pedro M. Q. Aguiar.

João Leonardo – "Limiar de Desempenho para Estimação Bayesiana de Parâmetros em variedades Riemannianas", supervised by João Xavier.

3.11 PUBLICATIONS

A) M.Sc. Theses (5)

[1] **Nuno Paulino,** "Terrain Tracking Control Strategies for Autonomous Vehicles with Applications to Unmanned Helicopters", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, March 2005.

[2] **Vasco Pires**, "Sistema de Decisão Distribuído Baseado em Lógica para uma Equipa Multi-Robot", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, July 2005.

[3] **José Inácio Rocha**, "Inspecção e Manutenção Robótica em Linhas de Transporte de Energia Eléctrica de Alta Tensão", Master Thesis, Instituto Superior Técnico, Lisboa, Portugal, September 2005.

[4] **Ricardo Marranita,** "Visual Tracking of Articulated Objects: an application to the Human Hand"**,** Master Thesis, Instituto Superior Técnico, Lisbon, Portugal**,** November 2005.

[5] **Nelson Ricardo Perdigão Pereira**, "Hybrid Evolutive Algorithm for Multiple Sequence Alignment", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2005.

B) Ph.D. Theses (3)

[6] **Paulo S. Felisberto**, "Data Fusion Applied to Ocean Acoustic Tomography", Ph.D. Thesis, University of Algarve, Portugal, April 2005.

[7] **Alberto Vale**, "Mobile Robot Navigation in Outdoor Environments: A Topological Approach", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2005.

[8] **Fernando Manuel Fernandes Melício**, "Horários Escolares Semanais por Simulated Annealing", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2005.

C) Books (as Editors) (2)

[9] **Jorge S. Marques, Nicolás Pérez de la Blanca, Pedro Pina**, (Eds.), Pattern Recognition and Image Analysis, Part I, Springer, Lecture Notes in Computer Science, ISBN: 3-540-26153-2, Vol. 3523, 703 p., 2005.

[10] **Jorge S. Marques, Nicolás Pérez de la Blanca, Pedro Pina**, (Eds.), Pattern Recognition and Image Analysis, Part II, Springer, Lecture Notes in Computer Science, ISBN: 3-540-26154-0, Vol. 3523, 733 p., 2005.

D) Chapters In Books (6)

[11] **Francisco A. Melo, Isabel Ribeiro, Pedro Lima**, "Navigation Controllability of a Mobile Robot Population", *RoboCup-2004: Robot Soccer World Cup VIII*, Springer Verlag, Berlin, Pages 499 – 507, 2005.

[12] **B. Van der Vecht, P. Lima**, "Formulation and Implementation of Relational Behaviours for Multi-Robot Cooperative Systems", *RoboCup-2004: Robot Soccer World Cup VIII*, Springer Verlag, Berlin, 2005.

[13] **P. Lima, L. Custódio**, "RoboCup 2004 Overview", *RoboCup-2004: Robot Soccer World Cup VIII*, Springer Verlag, Berlin, 2005.

[14] **P. Lima, L. Custódio**, "Multi-Robot Systems", Chapter I of *Innovations in Robot Mobility and Control*, S. Patnaik, S. Tzafestas, Eds., Springer Verlag, Berlin, 2005.

[15] **C. Fernandes, V. Ramos, A. Rosa**, "Varying the Population Size of Artificial Foraging Swarms on Time Varying Landscapes", W. Duch, J. Kacprzyk, E. Oja, S. Zadrozny (Eds.), *Artificial Neural Networks: Biological Inspirations*, LNCS series, Vol. 3696, Part I, pp. 311-316, Springer-Verlag, September 2005.

[16] **C. Munteanu, A. Rosa, M. Galan, E. R. Royo**, "Evolutionary Color Constancy Algorithm based on the Gamut Mapping Paradigm", LNCS 3643, pp. 404-409, 2005.

E) In International Journals (18)

[17] **J. Sequeira**, **M. I. Ribeiro**, "Robot Team Control: A Geometric Approach", *Journal of Robotics and Autonomous Systems*, Vol. 53, No. 1, pp. 59-71, 2005.

[18] **F. Cardigos, A. Colaço, P. R. Dando, S. Ávila, P. M. Sarradin, F. Tempera, P. Conceicão, A. Pascoal, R. Serrão Santos**, "Shallow water hydrothermal vent field fluids and communities of the D. João de Castro Seamount (Azores)," *Chemical Geology*, *Elsevier*, 224, pp. 153-168, 2005.

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[22] **R. Carvalho, L. Custódio**, "A Multiagent Systems Approach for Managing Supply-Chain Problems: new tools and results," *The Inteligencia Artificial Journal*, *Revista Iberoamericana de Inteligencia Artificial* – Special Issue on Iberagents 2004, Vol. 9, Nr 25, 2005.

[23] **E. Grossmann and J. Santos-Victor, "**Least-squares 3D reconstruction from one or more views and geometric clues", *Computer Vision and Image Understanding*, Vol. 99, No. 2, pp. 151-174, August 2005.

[24] **M. Lopes and J. Santos-Victor, "**Visual Learning by Imitation With Motor Representations", *IEEE Transactions on System Man and Cybernetics - Part B: Cybernetics***,** Vol. 35, No. 3, June 2005.

[25] **M. C. Lopes, A. Rosa, D. Poyares**, **S. Roizenblatt, C. Passarelli, S. Tufik**, "Cyclic Alternating Pattern in peripubertal Children", *Journal Sleep*, Vol. 28, Issue 2, pp. 215-219, 2005.

[26] **C. Guilleminault, J. Lee, A. Chan, M. Lopes, Y. Huang, A. Rosa**, "Non-REM-sleep instability in recurrent sleepwalking in pre-pubertal children", *Sleep Medicine*, Vol. 6, No. 6, pp. 515-513, 2005.

[27] **C. Guilleminault, D. Poyares, A. Rosa, Y. Huang**, "Heart rate variability, sympathetic and vagal balance and EEG arousals in Upper Airway Resistance and mild Obstructive Sleep Apnea Syndromes", *Sleep Medicine*, Vol. 6, No. 5, pp. 451-457, 2005.

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[32] **D. Poyares, C. M. Almeida, R. S. Silva, A. Rosa, C. Guilleminault**, "Violent Behavior During Sleep", *Revista Brasileira de Psiquiatria*, Suppl. 1, pp. 22-26, May 2005.

[33] **J. Nascimento, J. S. Marques**, "Adaptive Snakes Using the EM Algorithm", *IEEE Transactions on Image Processing*, Vol. 14, Issue 11, pp. 1678 – 1686, November 2005.

[34] **A. Martins, P. Aguiar, and M. Figueiredo**, "Orientation in Manhattan: Equiprojective Classes and Sequential Estimation", *IEEE Transactions on Pattern Analysys and Machine Intelligence*, Vol. 27, No. 5, 2005.

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[36] **L.M.B.C. Campos & J.M.G. Marques, "**On a combination of the Gamma and generalized error distributions with application to aircraft flight path deviations", *Communications in Statistics*, Vol. 33, 2005.

[37] **L.M.B.C. Campos,** "On some recent advances in aeroacoustics", *International Journal of Sound and Vibration*, 2005.

F) In International Conferences (64)

[38] **G. Neto, P. Lima**, "Minimax Value Iteration Applied to Robotic Soccer", *Proc. of ICRA2005 - IEEE Workshop on Cooperative Robotics*, Barcelona, Espanha, April 2005.

[39] **L. Montesano, J. Gaspar, J. Santos-Victor, L. Montano, "**Fusing vision-based bearing measurements and motion to localize pairs of robots", *Proc. of ICRA2005 – IEEE Workshop on Cooperative Robotics*, Barcelona, Spain, April 2005.

[40] **R. Carvalho, L. Custódio**, "A Multiagent System Approach for Managing Supply-Chain Problems: a learning perspective", *Proc. of KIMAS2005 - International Conference Integration of Knowledge Intensive Multi-Agent Systems*, Waltham, Massachusetts, USA, April 2005.

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[52] **P. Oliveira**, "PCA Positioning Sensor Characterization for Terrain Based Navigation of UVs", *Proc. of IbPRIA2005 - 2nd Iberian Conference on Pattern Recognition and Image Analysis*, Estoril, Portugal, June 2005.

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[56] **Rui M. Jesus, Arnaldo J. Abrantes, Jorge S. Marques**, "Relevance Feedback in CBIR using the RLS Classifier", *Proc. of the 5th EURASIP Conference focused on Speech and Image Processing, Multimedia Communications and Services*, Smolenice, Slovak Republic, June 29 – July 2, 2005.

[57] **R. Ghabcheloo, A. Pascoal, C. Silvestre,** "Nonlinear Coordinated Path Following Control of Multiple Wheeled Robots with Communication Constraints", *Proc. of ICAR 2005 - 12th International Conference on Advanced Robotics*, Seattle, Washington, USA, July 2005.

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[59] **I. Kaminer, A. Pascoal, O. Yakimenko**, "Nonlinear Path Following Control of Fully Actuated Marine Vehicles with Parameter Uncertainy," *Proc. 16th IFAC World Congress*, Prague, Czech Republic, July 2005.

[60] **C. Silvestre, A. Pascoal,** "Depth Control of the Infante AUV Using Gain-Scheduled Reduced-Order Output FeedBack", *Proc. of 16th IFAC World Congress*, Prague Czech Republic, July 2005.

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[62] **P. Oliveira**, "Terrain Based Navigation Tools for Underwater Vehicles using Eigen Analysis," *Proc. of the 16th IFAC World Congress*, Prague, Czech Republic, July 2005.

[63] **D. Dumitriu, P. Lima, B. Udrea**, "Optimal Trajectory Planning of Formation Flying Spacecraft", *Proc. of the 16th IFAC World Congress*, Prague, Czech Republic, July 2005.

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4.0 LABORATORY FACILITIES AND SERVICES

4.1 COMMON FACILITIES

ISR/IST has a computer network infra-structure based on 4 PC servers, providing basic services such as mail and web servers, shell accounts, firewall, among others (databases, mailing lists, etc.). The firewall provides IP connectivity (IPv4 and native IPv6) to the IST campus network. More than 150 users have accounts on the isr.ist.utl.pt domain (mail and/or shell), and more than 300 machines, including PCs, SUN workstations, Macintoshes and others, are currently linked to the network, using switching technology (Ethernet 10/100). Moreover, all ISR facilities are covered by the campus WiFi (802.11b/g) network, thus providing wireless access to the Internet.

4.2 LABORATORY FACILITIES

INTELLIGENT SYSTEMS Lab (IS)

The ISLab offers the main following facilities:

- 1 all-terrain remotely-operated (by wireless or cable LAN) robot (RAPOSA), endowed with several sensors for detection of dangerous gases, humidity, and temperature, a thermal camera, several web cams (some of them with controllable pan);
- 5 omni-directional (3 wheels) robots endowed with an on-board laptop with wireless communications, rate-gyro, 16 sonars, omni-directional catadioptric system, optical mouse for odometry, electromechanical kicker and rolling drum systems for robotic soccer applications;
- 1 RWI ATRV-Jr mobile robot, 4-wheel drive, equipped with 16 sonars, GPS, inertial navigation module and a compass, pan and tilt vision system and one SICK Laser scanner (*shared with the Mobile Robotics and Computer and Robot Vision Labs*);
- 1 Blimp aerial robot, with pan and tilt vision system, 3 servomotors, RF link for remote control and remote video-link for video transmission (*shared with the Mobile Robotics and Computer and Robot Vision Labs*);
- 4 Nomadic Super-Scout II mobile robots, equipped with 16 sonars and 2 cameras each, one of them part of an omni-directional catadioptric system;
- 14 Philips 740K USB Web Cams, used in the Super-Scout II robots;
- 1 Mobile Platform, built at ISR, with tricycle-like kinematics, 60W and 90W motors, open control and guidance architecture based on 2 Pentium motherboards, and 2 on-board cameras;
- 1 Real-Time RF video link;
- Matlab and Simulink software for different simulation projects;
- Several cameras, used for visual servoing and vision-based navigation applied to manipulators and mobile robots;
- 1 Space Mouse device, for teleoperation of mobile robots and manipulators;
- 1 PUMA 560 manipulator, whose Mark III controller was partially replaced by Trident Robotics TRC 004/6 boards, which allow manipulator control by an external PC;
- 35 Pentium Personal Computers (PIII or PIV, including 10 laptops, 4 of them for the omni-directional robots) – under Linux and Windows 2000/XP OS;

MOBILE ROBOTICS Lab (LRM)

The LRM offers the main following facilities:

- 2 Scout mobile platforms with on-board computer, vision camera and wireless Ethernet;
- 1 ATRV Jr Rover with ultrasound sensors, GPS and Inertial Measurement Unit. This mobile platform is shared with the Intelligent Systems and Computer Vision Laboratories;
- 4 Sony dogs Aibo, shared with the Intelligent Systems Lab;
- Robuter mobile platform, with a ring of 24 ultrasound sensors, and two on-boards processors: Motorola 68020@16MHz running the real-time operating system Albatros, and a Pentium@200Mhz running Windows NT. A laser scanner (Lasernet system) for localisation purposes with artificial landmarks is installed on the platform;
- A complete set of the LEGO Mindstorms system for Mobile Robotics;
- A Laser Range Finder from the Riegl supplier with range and luminance measurement;
- 3 Sick Laser Scanner;
- Three computer controlled Pan & Tilt Units from Direct Perception;
- Video cameras, including two Quick Cams and a Network Eye supporting direct display of real scenes on the Internet;
- 10 Pentium PCs + 5 portable Pentiums;
- Two laser printers, and one DeskJet colour printer;
- 5 kits Lego Mindstorms;
- 1 Robuter mobile platform;
- 1 GT6A serial manipulator;
- 1 PC with VME bus;
- 8 webcams;
- 2 ethernet switches 100Mbps;
- 1 ethernet access point;
- 5 USB wireless adapters;
- 2 pairs of ethernet modems from OTC;
- 1 oscilloscope (digital) Tektronix:
- A large open space appropriate for mobile robotics navigation experiments.

COMPUTER VISION Lab (VISLAB)

The VisLab is equipped with various PCs, various cameras (CCD, CMOS, Colour, Black & White, Digital or Analogue) and image frame grabbers, a pan-tilt unit and several pan-tilt cameras.

Special equipment consists of a high-speed 4 degrees of freedom binocular head – Medusa - developed for research in active vision, a TRC LabMate mobile platform, two Nomad Superscout mobile platforms, equipped with vision and an on-board computer. Additionally various home-made small robots have been developed and are used for experiments in the areas of vision based control.

More recently a smaller active vision head was built and installed on a mobile vehicle for experiments in vision based navigation with extra degrees of freedom. A humanoid robot encompassing an anthropomorphic arm and a torso supporting the binocular head Medusa, was assembled for conducting experimental research in learning by imitation (see pictures below). It is the only humanoid-like upper torso platform available and built in Portugal for research in sensorimotor coordination, computer vision and learning.

SIGNAL AND IMAGE PROCESSING GROUP (SIPG) – LISBON

The SP Lab offers capabilities to develop and test both software and hardware products for digital signal processing. Presently, the activities in course include the design, implementation and performance benchmarking of modems for underwater acoustic data communications, and testing of navigation and guidance techniques for autonomous robotics.

The SIPG offers the main following facilities:

- Intel-compatible personal computers;
- Hewlett-Packard LaserJet 4M printer;
- Xerox Phaser 8550 Color printer;
- 00 Mbit/s thin Ethernet LAN interfacing the Signal Processing Laboratory to the ISR Network;
- ORCA underwater acoustic communication system (surface modem with programmable acoustic receiver, underwater modem);
- Texas Instruments TMS320C6711 hardware/software DSP development systems;
- Motorola DSP96002 hardware/software DSP development system;
- Motorola software development system for the DSP56000 digital signal processor (DSP);
- 2 Xilinx field programmable gate array (FPGA) hardware/software development systems;
- 2 Signalware high-speed multichannel analog I/O boards for the TMS320C6711 DSP starter kit;
- National Instruments multifunction data acquisition boards (1 MIO-16E-4 PCI board, 2 PC-Cards) and LabView virtual instrumentation software;
- 1 National Instruments digital I/O PCI board;
- 1 TEAC CS-391 multichannel data recorder;
- 1 Goldstar OS-9040D 40 MHz analog osciloscope;

- 1 Hewlett-Packard HP8116A 50 Mhz function generator;
- 1 Escort EGC 3230 2 Mhz function generator with 100 Mhz frequency meter;
- 1 Sony F670ES power amplifier;
- 1 Kiotto KT-1990EX digital multimeter;
- 1 GW ST3030TD triple power supply;
- 1 Weller WTCP-S soldering station.

SIGNAL AND IMAGE PROCESSING GROUP (SIPG) – ALGARVE

- 1 room with 7 research desks + computer servers + electronics testing;
- bench internal 100/1000 Mb computer network w/router, NFS, printers;
- automatic backups, RAID5, etc...;
- 1 vertical line array (16 hyd) + radio buoy + acquisition system + wireless lan;
- 1 remote buoy with vertical line array and wireless lan;
- 2 acoustic oceanographic buoys (version 2);
- 1 260-900 Hz high power acoustic sound source (tomography);

DYNAMICAL SYSTEMS AND OCEAN ROBOTICS Lab (DSOR)

- **Mechanical / Electric shop** (8th Floor of ISR) - basic equipment and tools to machine mechanical pieces, assemble circuit boards, and test electrical / electronic circuitry.

Robotic Vehicles

- *DELFIM* **Autonomous Surface Vehicle (ASC)** - an autonomous surface craft (Catamaran-type) to carry out experimental research in the area of ocean robotics and to perform scientific missions at sea.

- *DELFIM_X* **Autonomous Surface Vehicle (ASC)** - an autonomous surface craft similar to the DELFIM, but with improved hydrodynamic characteristics.

- *INFANTE* **Autonomous Underwater Vehicle (AUV)** – an autonomous underwater vehicle to carry out experimental research in the area of ocean robotics and to perform scientific missions at sea.

- *CARAVELA 2000* **Autonomous Research Vessel** – prototype of an autonomous surface craft for long range missions at sea (co-owned by IST/ISR, IMAR/Dept. Oceanography and Fisheries of the Univ. Azores, RINAVE, and CONAFI)

- VARIO XTREM **R/C Helicopter** - a small helicopter (payload of 4 Kg) to carry out experimental research in the area of autonomous aerial robotics.

Small **Zodiac** to support operations at sea.

Mechanical/ Electrical Equipment

- **Pressure Chamber** - to test the marinization of equipment down to depths of 600 meters.
- **Crane** with the capacity to handle loads of up to 2500 Kg.
- **Industrial air compressor.**
- **Trailer for the transportation of marine vehicles.**

Actuators and Sensors for Robotic Ocean Vehicle Development and Operation (part of the equipment is dedicated to the operation of the INFANTE AUV and the DELFIM and CARAVELA ASVs).

- *Actuators* – 5 electrical thrusters.
- 3 rate gyros, 2 pendulums and 1 fluxgate (Watson's Attitude & Heading Reference Unit AHRS-C303);
- 3 rate gyros, 3 accelerometers and 1 magnetometer (SEATEX MRU-6)
- 3 rate gyros, 2 pendulums and 1 magnetometer (KVH attitude reference unit).
- 1 flowmeter TSA-06-C-A (EG & G Flow Technology);
- 2 depth cells DC 10R-C (Transinstruments);
- 2 echosounders ST200 (Tritech);
- 2 echosounders ST500 (Tritech);
- 1 Sidescan sonar (System Techonologies / Tritech);
- 1 Acoustic Modem for underwater communications (System Techonologies / Tritech);
- GIB (GPS Intelligent Buoys) – GPS based underwater positioning system, with target tracking capabilities.
- 1 Doppler Log TSM 5740 with 4 beams in a Janus configuration, operating at 300 KHz (Thomson-ASM);
- 1 Doppler Log, operating at 600 KHz, rated for 2000 m (RDI);
- 1 set of 3 rate gyros, 2 pendulums and 1 directional gyro from Humphreys.
- 1 *Long Baseline Positioning System* for underwater vehicle positioning - 1 transducer and 4 transponders.
- 1 *DGPS (Differential Global Positioning System)* for accurate surface vehicle navigation - 4 Motorola Encore unit and 3 FREEWAVE radios.

Hardware and Software Development Systems for Vehicle Simulation and Real-Time Vehicle Control

- *Hardware for real-time applications* - 3 Gespac 68030/68882 computers; a T805 transputer array; 4 MPL stand-alone 68020/60881 computers.
- *3 Single Board Computers RTD/USA*
- *Development System* - Microware FASTRAK development software running on a SUN-Workstation; professional OS9 for Gespac development systems.

Software Tools for Navigation, Guidance, and Control System Design

INTEGRA - Modeling and simulation tool for *the integrated analysis and design of navigation, guidance and control systems for autonomous vehicles.* The software was developed at IST/ISR and is built around the commercially available package MATLAB. The package is specially geared towards the development of dynamic models of robotic ocean vehicles. Furthermore, it provides the means to assess the combined performance of navigation, guidance and control systems prior to their implementation.

General Computer Facilities

11 Desktop PCs
7 Laptop PCs
2 Laser printers

EVOLUTIONARY SYSTEMS AND BIOMEDICAL ENGINEERING Lab (LASEEB)

The Laseeb offers the main following facilities on digital signal processing for biomedical engineering, digitalization and development for multimedia Applications:

- 20 Personal Computers running Windows 98/NT4/2000 and Linux;
- 2 Laser printer;
- 2 color inkjet printers;
- 1 Video Capture Board MIRO VIDEO DC30;

- 3 Cd-RW Recorders;
- 1 Tape Backup 12 Gb;
- 1 Scanner;
- 1 Biological amplifier Medelec;
- 1 Biological amplifier Braintronics;
- 1 Biological amplifier CAPS;
- 2x30 ch. A / D Acquisition DT 2834 16 Hz;
- 2x16 ch. A / D Acquisition DT 2821 150 Hz;
- 1x16 ch. A / D Acquisition DT 2811 30 Khz;
- 1x8 ch A / D Acquisition PCMCIA 50Khz.

In the new Laseeb Sleep Laboratory:

- Sonolab 632 from MEditron – Polysomnography Acquisition System;
- 1 Infrared Video Monitoring system from Meditron – sleep video;
- 1 LED bright light phototherapy from Meditron – Phase delay and advance therapy device;
- Med Supply A8000 from Meditron – CPAP machine;
- 1 Sonolab X1 from Meditron – Digital Pulse Oximetry;