# INSTITUTE FOR SYSTEMS AND ROBOTICS


# *Annual Report – 2004*

*Lisbon Pole*

♦

*Torre Norte, Piso 7*
*IST, Av. Rovisco Pais*
*1049 – 001 Lisboa*
*Portugal*

**Tel. + 351 21 841 82 89** **Web Server: http://www.isr.ist.utl.pt** **Fax. + 351 21 841 82 91**

## *Director*

***Prof. João José dos Santos Sentieiro***

## *Vice - Director*

***Prof. Maria Isabel Lobato de Faria Ribeiro***

***Torre Norte, 7º Piso***

***IST, Av. Rovisco Pais***

***1049 – 001 Lisboa***

***Portugal***

***Tel.: + 351 21 841 82 89***

***Fax.: + 351 21 841 82 91***

***e-mail: jjss@isr.ist.utl.pt***

# Table of Contents


OVERVIEW 1

1. ISR IN NUMBERS 3

2. RESEARCH TEAM AND INTERESTS 4

2.1 Members and Collaborators 4

2.2 Current Research Interests 6

*2.2.1 Intelligent Systems* 6

*2.2.2 Computer and Robot Vision* 8

*2.2.3 Mobile Robotics* 10

*2.2.4 Signal and Image Processing* 12

*2.2.5 Evolutionary Systems and Biomedical Engineering* 13

*2.2.6 Dynamical Systems and Ocean Robotics* 15

3. RESEARCH ACTIVITIES 25

3.1 Research Projects 25

*3.1.1 Underwater and Ocean Robotics* 25

*3.1.2 Cooperative Robotics* 33

*3.1.3 Image Processing* 37

*3.1.4 Underwater Acoustics* 39

*3.1.5 Computer Vision* 42

*3.1.6 Artificial Intelligence* 45

*3.1.7 Communications* 46

*3.1.8 Unmanned Air Vehicles* 48

*3.1.9 Space Applications* 50

3.2 Post-Docs Activities Report 52

*3.2.1 Activity Report of **Dan Dimitriu*** 52

*3.2.2 Activity Report of **Ettore Barros*** 52

*3.2.3 Activity Report of Jacinto Nascimento* 54

**3.3 Theses** **55**

*3.3.1 Theses Concluded during 2004* **55**

*3.3.2 Theses in Progress during 2004* **62**

**3.4 Advanced Training** **74**

*3.4.1 Courses* **74**

*3.4.2 Seminars* **74**

*3.4.3 Visits Abroad* **76**

*3.4.4 Supervision of Students Enrolled in Foreign Universities* **76**

**3.5 Congress, Meetings and Presentations** **78**

*3.5.1 Invited Talks* **78**

*3.5.2 Participations* **79**

**3.6 Service Activities** **81**

*3.6.1 Editorial Boards* **81**

*3.6.2 Advisory Boards* **81**

*3.6.3 Programme and Technical Committees* **82**

*3.6.4 Chairperson* **84**

*3.6.5 Reviewers* **85**

*3.6.6 Other Activities* **88**

**3.7 Academic Activities** **90**

**3.8 Distinguished Visitors** **93**

**3.9 Special Events** **94**

*3.9.1 ROBOCUP2004* **94**

*3.9.2 ROBOCUP Symposium 2004* **94**

*3.9.3 3rd ISLAB WorkShop* **95**

*3.9.4 4th ISLAB WorkShop* **95**

*3.9.5 IAV2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles* **95**

*3.9.6 Maritime Rapid Environmental Assessment'04 Sea Trial* **96**

*3.9.7 Acoustic Tomographic Monitoring System'04 Sea Trial* **97**

*3.9.8 SPAWC – 5th IEEE International Workshop on Signal Processing Advances for Wireless Communications* **97**

**3.10 Awards and Patens** **98**

**3.11 Publications** **99**

**4. LABORATORY FACILITIES AND SERVICES** **110**

**4.1 Common Facilities** **110**

**4.2 Laboratory Facilities** **110**

## *OVERVIEW*

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 2004[1] 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; trying to endow researchers with the infra-structures and technical personnel required for the development and testing of ocean equipment and vehicles.

In 2004 ISR 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. Seminars were organized in a regular basis, including a monthly seminar 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 2004, 146 senior and junior researchers have developed their research activities within ISR (Lisbon Pole). These included 28 professors, 1 Principal Researcher, 3 post-docs, 43 Ph.D. Students, 18 M.Sc. Students and 34 undergraduate research trainees.

During 2004, 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. As a result of these activities 8 M.Sc. and 3 Ph.D. theses were concluded, 6 papers where published in books, 26 papers were published in well known international journals, and 66 papers presented at prestigious international conferences. Steps keep being taken to encourage researchers to increase the publication of their research results in archive journals. Also the number of publications by Post-Docs is, in general, beyond expected and hence efforts should be made by their supervisors in order to change the situation.

The training of young researchers has pursued, involving 43 Ph.D. Students (Portuguese and foreigners) and 18 M. Sc. Students (Portuguese). Three researchers have concluded their doctoral theses, and 8 researchers have concluded their M.Sc. theses. Also, young licentiates from several European countries have come to participate in short and medium term research initiatives.

Several ISR researchers have stayed short or long periods abroad, as visiting or invited professors, researchers or students. Several foreign senior and junior researchers have visited and stayed with ISR.

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

In 2004 ISR organized three major scientific events that largely contribute to enlarge the international visibility of the institution: the RoboCup2004, with around 1600 participants from 37 countries and an estimated number of 500 robots split by 346 teams, the IFAC Symposium on Intelligent Autonomous Vehicles and the IEEE International Workshop on Signal Processing Advances for Wireless Communications.

As closing remarks I would like to stress the fact that despite the financial difficulties, that persisted during part of 2004, the international visibility of ISR and in particular of some of his groups has increased. This fact translates on the

[1] In 2004, 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 that will be described in a different report.

international contacts leading to collaboration projects and in the interest that Workshops and Conferences organized by ISR are raising in the scientific community.

Due to 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, we have not been able to initiate the process of contracting new researchers, both post-docs and PhD students. It is my belief that if FCT does not urgently fulfill the agreement signed with ISR in 2001, concerning the plurianual financing and the hiring of 14 new post-doc researchers and 4 technical staff, it will be no longer possible to maintain the degree of excellency that has been recognized to our institution by the independent international evaluation panels. Also, if the "re-equipment program" launched by FCT in 2001 and with results made public in the summer 2004, is not efficiently handled to completion, top institutions like ours will have to review their strategic objectives, with natural negative consequences for the progress of science and technology in Portugal.

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.

João Sentieiro
ISR, April 19, 2005

## *1. ISR IN NUMBERS*

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

# 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)*
Dan DUMITRIU, *Post-Doctoral St., ESA grantee*
Sónia MARQUES, *Adj. Professor (IPS), Ph.D. St.*
Rodrigo VENTURA, *Teaching Assistant (IST), Ph.D. St.*
Pedro FAZENDA, *Teaching Assistant (ISEL), M.Sc. St.*
Bruno DAMAS, *Teaching Assistant (IPS), M.Sc. St.*
Dejan MILUTINOVIC, *Ph.D. St., FCT grantee*
Andrés GARCÍA, *Ph.D. St., FCT grantee*
Hugo COSTELHA, *Ph.D. St., FCT grantee*
Gonçalo NETO, *Ph.D. St., FCT grantee*
Pedro PINHEIRO, *M.Sc. St.*
Miguel ARROZ, *M.Sc. St.*
Vasco PIRES, *M.Sc. St.*
Carla PENEDO, *M.Sc. St.*
João PAVÃO, *M.Sc. St.*
Pedro NUNES, *M.Sc. St.*
Constança SOUSA, M.Sc. *St.*
João FRAZÃO, *Research Assistant, AdI grantee*
João COSTAL, *Research Assistant, EUCLID RTP9 grantee*

Francisco MENDONÇA, *Undergrad. St.*
Luis PEREIRA, *Undergrad. St.*
Pedro INÁCIO, *Undergrad. St.*
Hugo VEIGA, *Undergrad. St.*
Sérgio LOPES, *Undergrad. St.*
Catarina ESTEVES, *Undergrad. St.*
João MILHINHOS, *Undergrad. St.*
Gonçalo MOURO VAZ, *Undergrad. St.*
Marco BARBOSA, *Undergrad. St.*
Nelson RAMOS, *Undergrad. St.*
João SANTOS, *Undergrad. St.*
João ESTILITA, *Undergrad. St.*

**COMPUTER AND ROBOT VISION:**

João SENTIEIRO, *Full Professor (IST), ISR/IST Director*
José SANTOS-VICTOR, *Associate Professor (IST)*
João Paulo COSTEIRA, *Assistant Professor (IST)*
José António GASPAR, *Assistant Professor (IST)*
Alexandre BERNARDINO, *Assistant Professor (IST)*
Plínio Moreno LÓPEZ, *Ph.D. St.*
Manuel Cabido LOPES, *Ph.D. St.*
Ricardo OLIVEIRA, *Ph.D. St.*
Roger Alex de FREITAS, *visiting Ph.D. St.*
Raquel Frizzera VASSALO, *visiting Ph.D. St.*
Sandra Esperanza Nope RODRIGUEZ, *visiting Ph.D. St.*
Pedro Canotilho RIBEIRO, *Ph.D. St.*
Ricardo MARRANITA, *M.Sc. St.*
Ricardo BEIRA, *Researcher, M.Sc. St.*
Miguel M. Lopes PRAÇA, *Industrial Designer*
Rodrigo JACOB, *Research Engineer*
Ricardo Jorge dos Santos FERREIRA, *Researcher*

**EVOLUTIONARY SYSTEMS AND BIOMEDICAL ENG.**

Agostinho ROSA, *Associate Professor (IST)*
Fernando MELÍCIO, *Coord. Professor, Ph.D. St.*
Rogério LARGO, *Adjoint Professor, Ph.D. St.*
José MALAQUIAS, *Teaching Assistant, Ph.D. St.*
Rui TAVARES, *Teaching Assistant, Ph.D. St.*
Carlos FERNANDES, *Teaching Assistant, Ph.D. St.*
João Paulo CALDEIRA, *Teaching Assistant, Ph.D. St.*
Osvaldo BRASÃO, *Ph.D. St.*
Hongfei GONG, *Ph.D. St.*
Cristian MUNTEANU, *Ph.D. St.*
Ernesto SOARES, *Ph.D. St.*
Raquel CÉSAR, *Ph.D. St.*
Julhison JUNIOR, *Ph.D. St.*
Nelson *PERDIGÃO, M.Sc. St.*
Ivo BHATT, *M.Sc. St.*
Alexandre CALAPEZ *M.Sc. St.*

Henrique PEREIRA, *Research Project*
Paulo SILVA, *Research Project*

***Collaborators***
Maria C. L. CONCEIÇÃO, *UNIFESP – Stanford Sleep Clinic*
Nuno COSTA, *Mildio and Mosca Project*
Fernando CONTREIRAS, *Mildio and Mosca Project*

Teresa Maria de Andrade ROSADO, *Undergrad. St.*
João M. S. DIAS, *Undergrad. St.*
André R. S. ROSADO, *Undergrad. St.*
Bruno M. R. LEAL, *Undergrad. St.*
Francisco FERNANDES, *Undergrad. St.*
João Miguel R. TAVORA, *Undergrad. St.*
Nuno M. C. P. FERNANDES, *Undergrad. St.*

**MOBILE ROBOTICS:**

Maria Isabel RIBEIRO, *Associate Professor (IST), ISR/IST Vice-Director*
João SEQUEIRA, *Assistant Professor (IST)*
Alberto VALE, *Ph.D. St.*
Francisco MELO, *Ph.D. St.*
José Inácio ROCHA, *M.Sc. St.*
Carlos ALFARO, *M.Sc. St.*
João CASALEIRO, *M.Sc. St.*
Sérgio GUERREIRO, *Collaborator*

Armando FONSECA, *Undergrad. St.*
Luis JORGE, *Undergrad. St.*
Ricardo FERREIRA, *Undergrad. St.*
Pedro SOARES, *Undergard. St.*
Tiago TELES, *Undergrad. St.*
Pedro CRUZ, *Undergrad. St.*
Pedro AGOSTINHO, *Undergrad. St.*
Mário FLORÊNCIO, *Undergrad. St.*

**SIGNAL PROCESSING (IST):**

Victor BARROSO, *Full Professor (IST)*
Isabel LOURTIE, *Associate Professor (IST)*
Jorge S. MARQUES, *Associate Professor (IST)*
Carlos BISPO, *Assistant Professor (IST)*
Pedro M. Q. AGUIAR, *Assistant Professor (IST)*
Francisco GARCIA, *Assistant Professor (IST)*
João Pedro GOMES, *Assistant Professor (IST)*
João XAVIER, *Assistant Professor (IST)*
João SANCHES, *Assistant Professor (IST)*
*Paulo GONÇALVES, Doctor, Visiting Researcher, INRIA, France*
Jacinto NASCIMENTO, *Post-Doctoral St.*
Marko BEKO, *Ph.D. St.*
Rui F. C. GUERREIRO, *M.Sc. St.*

Bernardo E. PIRES, *Undergrad. St.*
João SOUSA, *Undergrad. St.*
João LEONARDO, *Undergrad. St.*
Pedro R. G. BRANTES, *Undergrad. St.*
Fernando C. F. GONÇALVES, *Undergrad. St.*

**SIGNAL PROCESSING (U. ALGARVE):**

Sergio M. JESUS, *Associate Professor (UALG)*
Hans du BUF, *Invited Associate Professor (UALG)*
Hamid SHAHBAZKIA, *Assistant Professor (UALG)*
Orlando C. RODRIGUEZ, *Assistant Professor (UALG)*
Joao RODRIGUES, *Adjoint Professor, Ph.D. St.*
Paulo A. S. FELISBERTO, *Adjoint Professor, Ph.D. St.*
Antonio J. SILVA, *Adjoint Professor, Ph.D. St.*
Roberto LAM, *Invited Adjoint Professor, Ph.D. St.*
Pedro GUERREIRO, *Invited Adjoint Professor, Ph.D. St.*
Cristiano SOARES, *Ph.D. St.*
Nelson E. MARTINS, *Ph.D. St.*
Samuel NUNES, *Ph.D. St.*
Daniel ALMEIDA, *Ph.D. St.*
Eddy LOKE, *Ph.D. St.*
Luis FARINHA, *Res. Engineer*
Freiderich ZABEL, *Undergrad. St.*
Celestino MARTINS, *Undergrad. St.*

**DYNAMICAL SYSTEMS AND OCEAN ROBOTICS:**

António PASCOAL, *Associate Professor (IST)*
Carlos SILVESTRE, *Assistant Professor (IST)*
Paulo OLIVEIRA, *Assistant Professor (IST)*
Ettore BARROS, *Post-Doc Researcher, Gov. Brasil grantee*
Rita CUNHA, *Ph.D. St., FCT grantee*
Francisco TEIXEIRA, *Ph.D. St., FCT grantee*
Sajjad FEKRIASL, *Ph.D. St., FCT grantee*
Reza GHABCHELOO, *Ph.D. St., FCT grantee*
Danilo CARVALHO, *Ph.D. St.*
Alex PENA, *Ph.D. St., FCT grantee*
José VASCONCELOS, *Ph.D. St., FCT grantee*
Nuno PAULINO, *Msc. St.*
Bruno CARDEIRA, *Msc. St.*
Carla VIVEIROS, *Msc. St.*
Havard *BO, Msc. St., Norwegian Univ. Science and Techn*
Christian SKAAR, *Msc. St., Norwegian Univ. Scien*
*Technology*
João ALVES, *Research Assistant, AdI grantee ,M.Sc.St.*
Luis SEBASTIÃO, *Research Assistant, AdI grantee*
Manuel RUFINO, *Research Assistant, AdI grantee*

**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 6 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)

The ISLab driving theme is the *Research and Development on Multi Robotic Agent Systems* and involves the following research topics:

**Multi Agent Systems -** to study formal modelling tools adequate to develop and organize a team capable of dealing with complex and dynamic environments, working coherently as a group of agents, handling different and even opposite views of the world and the problem within the team, allowing flexible communication among team members, evaluating the team performance and implementing re-organization strategies to handle unexpected situations.

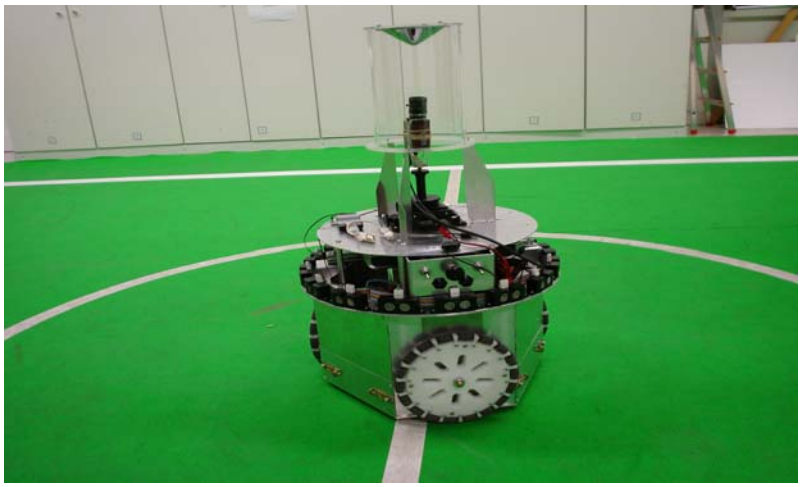
**Hybrid and Discrete Event Systems** - for robotic task modelling, supervision and coordination, so as to provide means for analysis and synthesis from desired qualitative and quantitative specifications, such as the absence of deadlocks or live locks, unreachable unsafe states, deterministic or probabilistic execution time.

**Cooperative Reinforcement Learning -** as an approach to iterative stochastic decision making, during the coordinated execution of robotic tasks, and without full knowledge of the environment model, as well as a quantitative evaluation of robotic task performance.

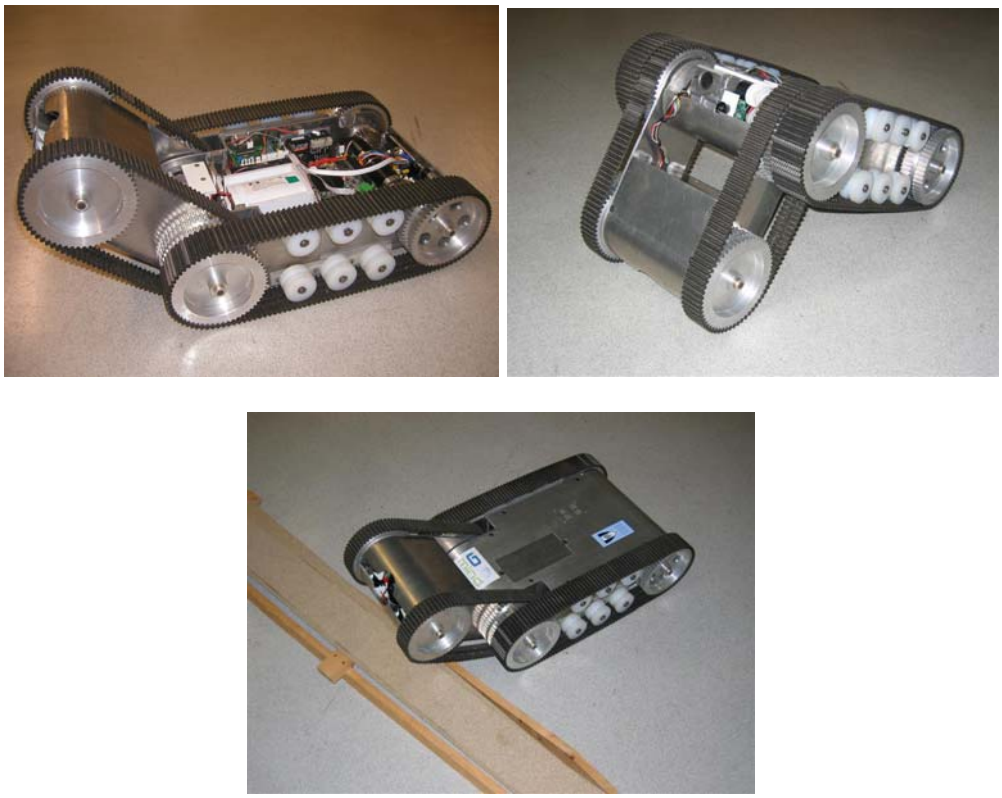
**Formation Guidance, Control, Navigation and Coordination –** GNC methodologies for several robots in formation, including free flyers and land robots, as well as its coordination with the task under execution.

**Emotion-based Agents -** to study methodologies for developing emotion-based agents, which is an entity 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.

The group is currently interested in applications to *Soccer Robots*, *Rescue Robots*, *Manufacturing Systems*, and *Satellite Formations*.



New omni-directional soccer robot, developed together with Portuguse companies IdMind and ServiLog, within the framework of the FCT Project SocRob



RAPOSA Rescue robot (almost-final prototype), developed together with Portuguese companies IdMind and SetPontes, within the framework of the AdI Project RAPOSA

## 2.2.2 COMPUTER AND ROBOT VISION (VIS)

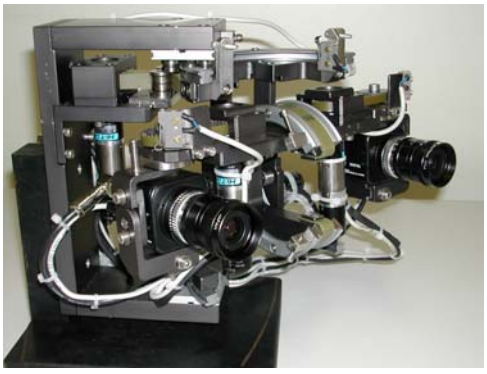
The research conducted at the Vislab is organized in two main lines:

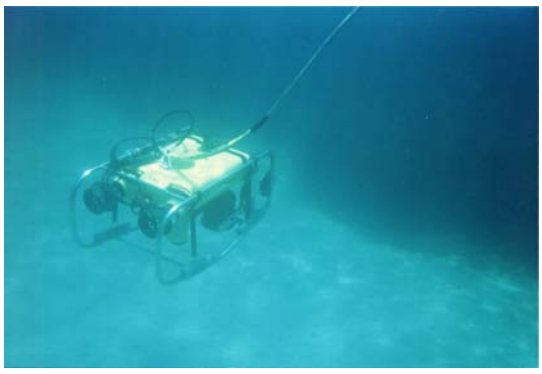
- Vision Based Control and Navigation
- 3D Motion analysis and Reconstruction

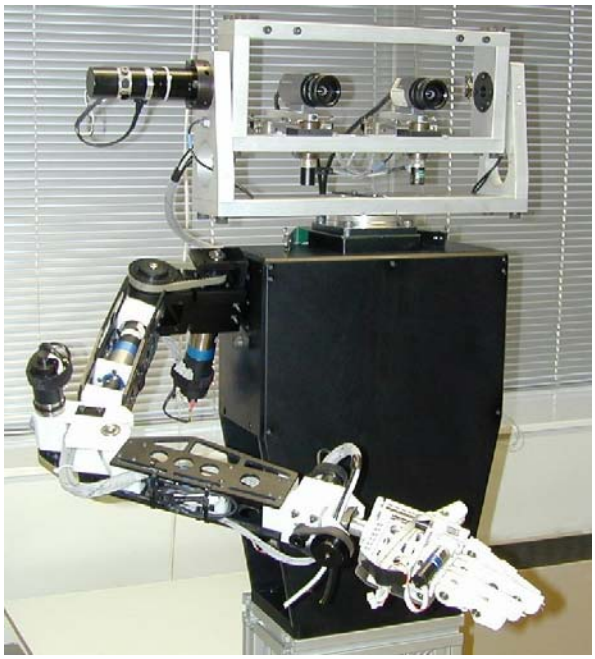
When a camera is moving in a static (or dynamic) environment, the image sequence conveys information regarding the scene/objects structure and camera/objects motion.

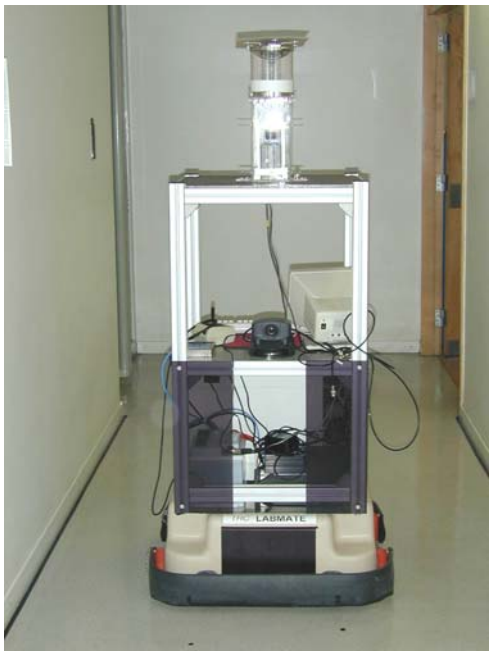
In the theme of ***Vision Based Control and Navigation***, we address the fundamental problems of understanding what *relevant* information can be extracted from the image sequences to *control* a robot in order to perform a *given task*. This has been a long standing research line of the Vislab including the control of extremely varied systems: the active control of a binocular head, teaching a humanoid-type robot by imitation, 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. 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. 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.

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. This work is pursued in conjunction with teams of neuroscientists or developmental psychologists.









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.

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 (MR)

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 modeling a multi-robot population as an automata and the analysis of the automata to yield controllability properties of the population. This tool is of use in the purging of individual navigation paths which may prevent the achievement of the goal for the population. It can be used in a decentralized architecture for coordination purposes. Experiments on cooperative localization of a robot team are being carried out based 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 (SP)

- Statistical and Array Signal Processing
- Wireless Communication Systems
- Channel estimation and equalization
- Fast and numerically stable algorithms for adaptive filtering
- Underwater digital communications
- Time-reversal acoustics
- Ocean acoustic propagation modeling
- Array processing
- Software-defined radio
- Detection and Estimation Theory
- Time-Frequency Signal Analysis and Processing
- Medical applications
- Pattern recognition
- Image analysis
- Computer vision
- Video processing
- Multimedia signal processing

## SP at University of Algarve

**Broad Areas of Research:**

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

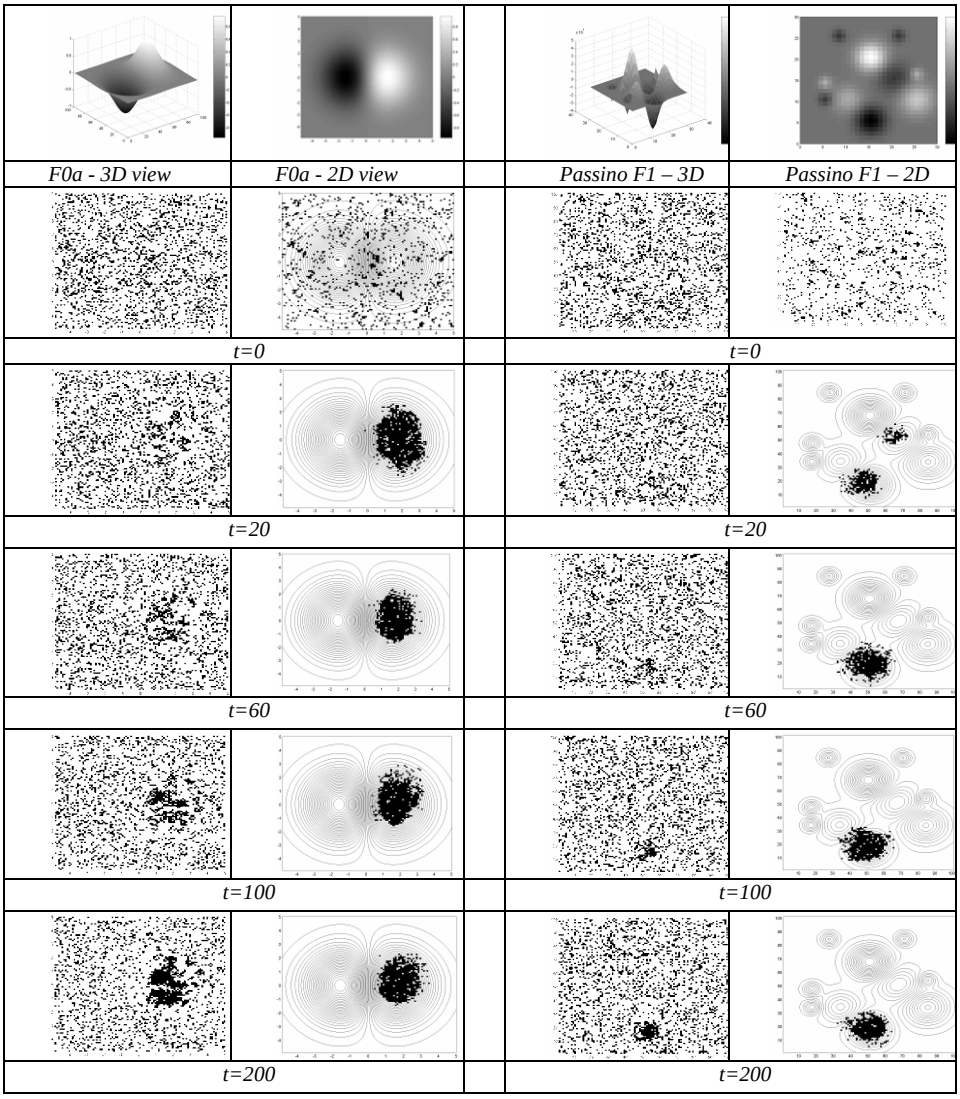
**Applied Research:**

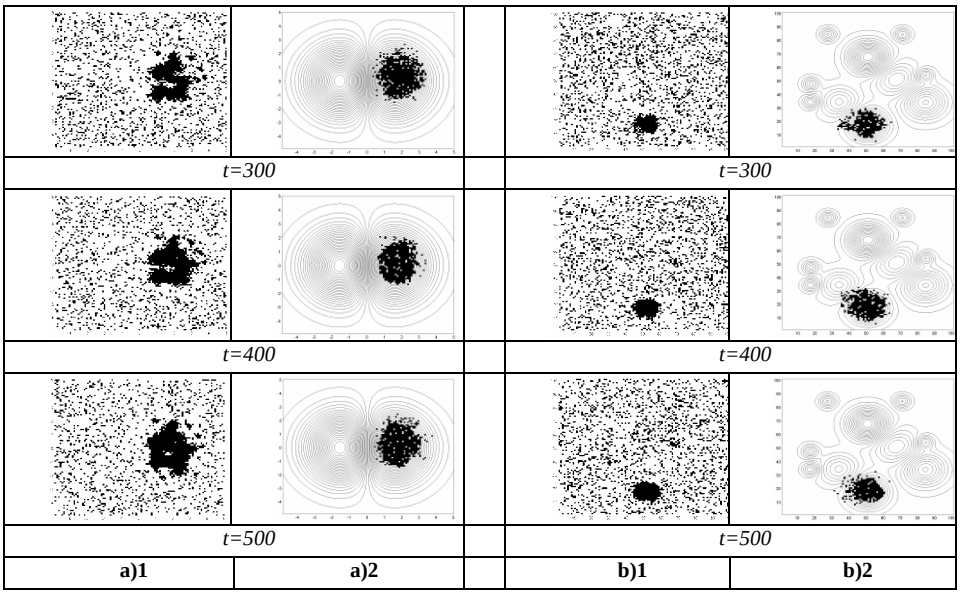
- Acoustic Rapid Environmental Assessment
- Acoustic and Non-acoustic Data Assimilation
- High Frequency Acoustic Propagation
- Underwater Communications via Environmental-based Time-Reversal
- Environmental-based Source Localization and Development of Acoustic-Oceanographic Buoy Systems

## 2.2.5 EVOLUTIONARY SYSTEMS AND BIOMEDICAL ENGINEERING (ESBE)

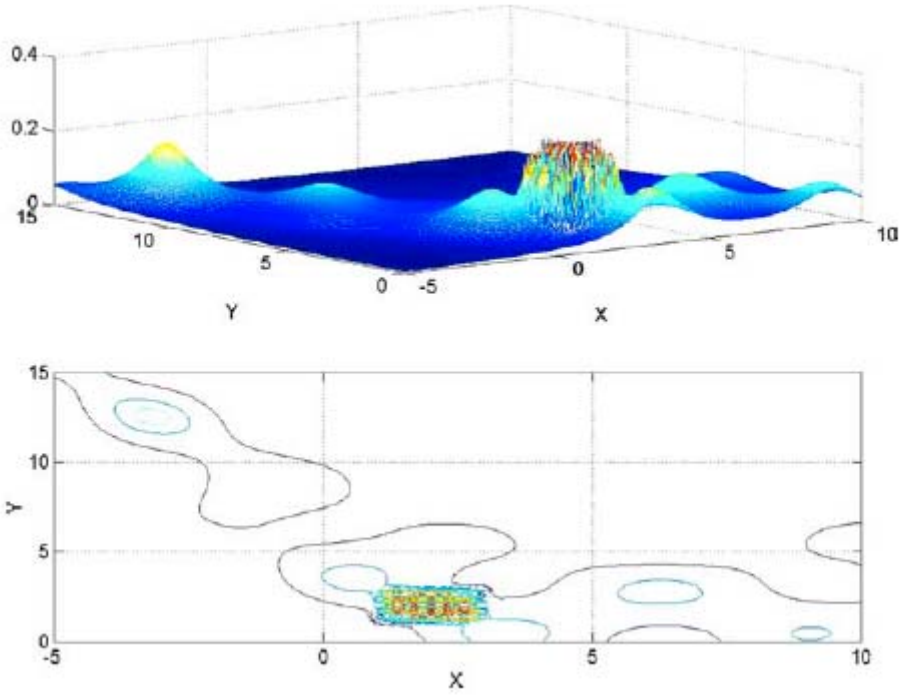
The research work of this group focus on biologically inspired new algorithms and paradigms for search and optimization and biomedical signal and imaging processing algorithms. The potential of the results have been demonstrated in applications. A few recent results will be presented below.

- **In the Evolutionary Algorithms**: The successful adaptation of the Olive Fly Model (*Bractocerao olea*)using Evolutionary Approach has captured the interest of the National Plant Protection Department, where is under negotiation the implementation of a nation wide simulation and decision support system based on this concept. This concept has been extended to the *Mildium mildew* advanced simulation and warning system. Hybrid method of Protein/base Multiple Sequence Alignment is ready and currently the solutions obtained converged to the Balibase Protein alignment benchmarking database. Collective search paradigm has been studied and communications rules have been formulated and tested for enhanced social influence search algorithms. A new machine intelligence modelling and acquisition paradigm has been formulated and it is currently under validation. A new topic of research in this area is the use of Swarm Stigmergy and Self-organization paradigms under varying environment and population size. The first results are shown in the figure below.






- **In the Biomedical Engineering** area, the group has contributed to the research and normalization in children population of the Cyclic Alternating Pattern paradigm for NREM sleep microstructure. A Pilot study on Stimulated Dream and Sleep has been finished and a specific project will be start shortly. A new paradigm for Classification and Dynamic organization of Phasic Events in the Sleep EEG code named "ascending Activation is currently evolving. The main task is the definition of the events alphabet based on phasic rhythms with physiological relevance. An Evolutionary Algorithms (ARGA) adapted rule based classification systems for automatic CAP analysis using wavelet decomposition has reached its final stage of development.



## 2.2.6 DYNAMIC SYSTEMS AND OCEAN ROBOTICS (DSOR)

Over the past decade, there has been tremendous progress towards the development of advanced robots for operations at sea. 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 data acquisition, they hold great potential to drastically simplify the task of acquiring ocean 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.

**Over the past years, the ISR/IST 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. 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 has 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 two 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 DSORL 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 DSORL 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. 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**. Accordingly, the main thrust of the work done at the DSORL is 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 robotic systems *modelling* and ***robust and 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 highly performing systems for autonomous marine and air robots. The latter are expected to play an important role in the study of coastal systems (including fast mapping of sand dunes and studying the evolution of their volumetry), as well as in missions that require the coordinated operation of air and surface craft.
- Studying and developing algorithms for **feature-based navigation of autonomous underwater vehicles** by resorting to acoustic bathymetric terrain data and geomagnetic data.
- Developing strategies for **coordinated control of multiple autonomous vehicles** that are well rooted in nonlinear system theory.
- Advancing the development of software and hardware for the development of prototypes equipped with real-time operating systems for **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, Brasil, Norway, France, and the USA. At the same time, the group pursued 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 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 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).
- Istituto Automazione Navale, Genova (Italy).
- National Institute of Oceanography, Goa (India) – a memorandum of understanding has been signed by 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).
- IMAR/DOP/UAçores - 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/UAçores and CREMINER/FCUL, under Theme A (Techniques for Ocean Exploration) of the Laboratório Associado (Associated Laboratory) that is coordinated by ISR. 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. The balance between the two factors is often hard to strike and requires the concerted action of many researchers / engineers, with expertise that runs across a number of technical fields. In 2004, 5 MSc, 7 PhD, and 1 PostDoc student, together with 3 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 J. Alves) are senior researchers, have contributed very positively 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/UAçores in the definition of vehicle requisites, selection of scientific sensor suites, and the tremendous logistic support (lab space, support vessels and manpower) given during the missions in the Azores.

At a ***theoretical*** level, and following the main trend established over the past three 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**. Coordinated navigation and motion control of multiple vehicles (air and marine robots) in the presence of strict acoustic communication constraints (low bandwidth, latency, drop-outs and multi-path effects).

**T5.** Modelling, Parameter Estimation and Identification, and Integrated Plant-Controller Design for Marine Vehicles.

**T6**. Multiple Vehicle Mission Control techniques

At a ***practical*** level, the emphasis is being placed on the following tasks:

**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, basic 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.

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

The work of doctoral student Sajjad FekriAsl, supervised by Profs. Michael Athans and António Pascoal, has led to 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 progressed to a level where a systematic way of designing **robust adaptive controllers for multiple-input multiple-ouput plants with parametric uncertainty and unmodeled dynamics** is starting to emerge. However, considerable work remains to be done to extend the techniques developed so far for a large number of uncertain parameters.

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

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 the 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. Both problems are being studied at ISR/IST. Considerable emphasis has been placed on the following key aspects of navigation:

i) Development 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.

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. 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. This work is being done by PhD student Alex Peñas, under the supervision of Prof Paulo Oliveira and the co-supervision of Prof. António Pascoal.

iii) Study and evaluation of the performance of algorithms for **feature based navigation**. In the case of marine robots, this entails the use of bathymetric and geomagnetic data. Navigation systems design for long range missions of underwater vehicles (UVs) in unstructured environments, without resorting to external sensors, and with bounded error estimates, has been a major challenge in underwater robotics. Unmodelled dynamics, time-varying phenomena, and the noise present in the sensor measurements continuously degrade the navigation system accuracy along time, precluding its use on a number of interesting applications. To overcome this limitation, external positioning systems have been proposed and successfully operated in the past, and integrated in navigation systems for underwater applications. Unfortunately, all those positioning systems only provide locally accurate measurements (a few square kilometres), take long time to deploy, and are hard to calibrate, strongly constraining the missions that can take place, and ultimately the use of UVs.

One alternative central to this work has been exploited in the past: in the case where the missions take place in areas where detailed bathymetric data are available, the terrain information can be aid to bound the error estimates of the navigation systems leading to Terrain Based, Terrain Reference, or Terrain Aided Navigation Systems. Applications with relative success have been reported in the past for air, land and underwater robotic platforms.

In 2004, Prof. Paulo Oliveira carried out a research effort to propose an alternative solution for this problem, based on the use of unsupervised optimal processing techniques of random signals, namely Principal Component Analysis (PCA) (based on the Karhunen-Lo`eve Transform). The performance was studied in 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. In this way, the use of a nonlinear positioning sensor instead of a nonlinear estimator is proposed. Moreover, the development of tools for Terrain Based Navigation rooted on Principal Component Analysis are proposed and discussed in detail. Resorting to a nonlinear Lyapunov transformation, the synthesis and analysis of a nonlinear multi-rate $H2$ estimator was studied, with guaranteed stability and optimal performance, over equilibrium trajectories. Post-processing techniques resorting to a fixed interval non-causal smoother were also proposed to improve the performance of the overall solution. The results obtained pave the way to the use of the proposed sensor in real positioning applications for underwater robotics. Future work will be carried out on the implementation of multi model adaptive estimator design and analysis tools for underwater navigation systems, where Doppler log/PCA and INS/PCA systems are of interest.

In parallel, doctoral student Francisco Teixeira (under the supervision of Prof. António Pascoal) carried out research on the subject of underwater vehicle navigation using bathymetric by exploring key concepts that borrow from the field of SLAM (Simultaneous Localization and Mapping). 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.) Encouraging 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. Future work will address the use of a multibeam sonar to fully explore spatial diversity, as well as the magnetic signature of the terrain being covered for local navigation using magnetometers or gradiometers. Interestingly enough, an extensive survey reveals that only a few papers on the latter issue have appeared in the literature.

**T4. Coordinated navigation and motion control of multiple vehicles (air and marine robots) in the presence of strict acoustic communication constraints (low bandwidth, latency, drop-outs and multi-path effects).**

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.

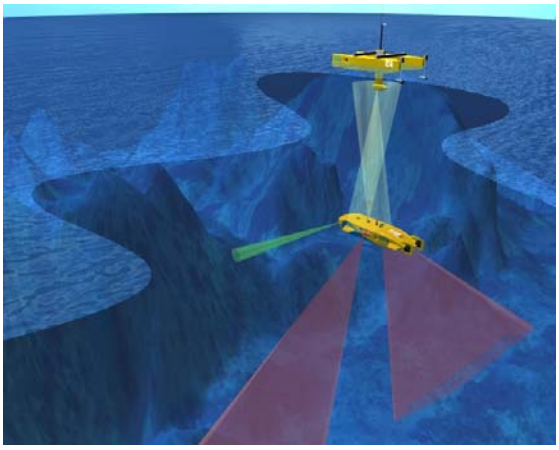
In recent years, there has indeed been widespread interest in the problem of coordinated motion control of fleet of autonomous vehicles. Applications include aircraft and spacecraft formation flying control, aircraft control, coordinated control of land robots, and control of multiple surface and underwater vehicles.The work reported in the literature addresses a large class of topics that include, among others, leader/follower formation flying, control of the "center of mass" and radius of dispersion of swarms of vehicles, and uniform coverage of an area by a group of surveying robots, to name but a few. This trend is also visible in military applications, where strict performance requirements coupled with the challenging conditions of planned space flight missions dictate the use of multiple autonomous exploration vehicles. As an example, the DARPA-program in the USA addresses relevant technological developments in this area. On a different but related vein, there is also increasing interest of the European Space Agency (ESA) on the challenging problem of multiple satellite formation flying. The

possible use of teams of mobile systems was also analyzed by NASA/JPL (in the context of the Mars Research Program) for the execution of complex tasks involved in mining. Interestingly enough, related problems arise in the cooperation of mobile systems competing in the widely popular robot soccer.

Spawned by the advent of small embedded processors and sensors, advanced communication systems, and the miniaturization of electro-mechanical devices, considerably effort is now being placed on the deployment of groups of networked vehicles in a number of challenging environments. However, the underlying theoretical issues that must be resolved and the complexity of the supporting software / hardware architectures required to actually implement the coordination schemes for groups of cooperating heterogeneous uninhabited systems are far from being trivial. This situation is specially acute in the case of systems designed for operations at sea because of the extremely adverse operating conditions encountered (large depth and therefore pressure, corrosion, lack of reliable communications and navigation, etc.). Among the problems that are currently being addressed we cite multiple vehicle control in the presence of uncertainty, noise, and disturbances, coupled control/logic communication design, control and navigation in the presence of unreliable acoustic communication links, robustness to hardware malfunctions and failures, complex hierarchical operating objectives, and high level coordination/management requirements.

These problems pose considerable challenges to systems engineers, 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.

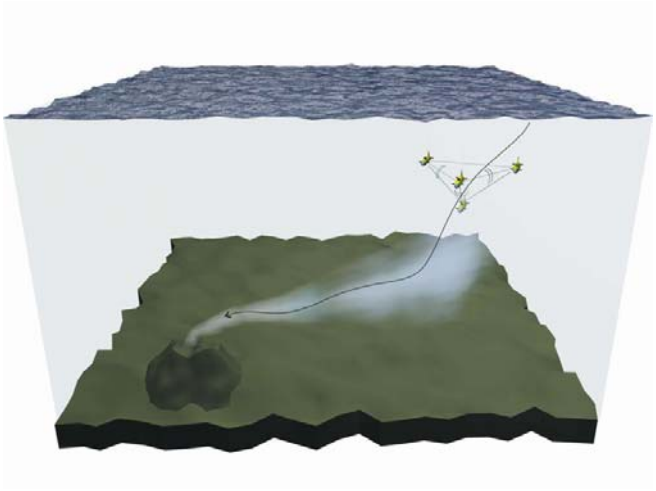
At ISR/IST, there has been considerable research activity in this vibrant area towards the development of algorithms for coordinated motion control of marine vehicles. The interest of the group in this area goes back to approximately 10 years ago, when the so-called ASIMOV concept was first proposed 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.



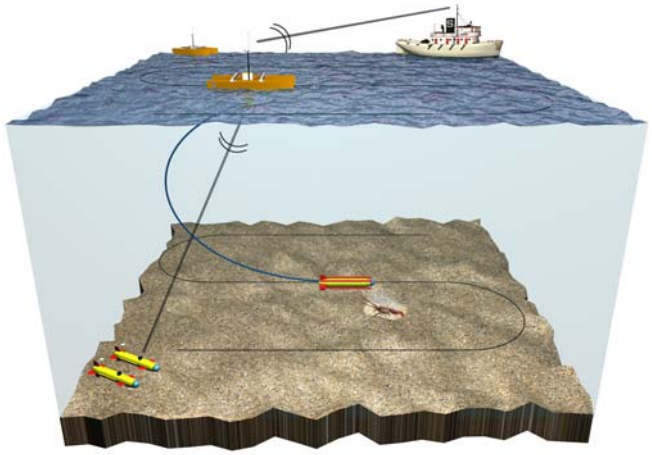
Combined autonomous surface craft / autonomous underwater vehicle control.

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: i) 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, and ii) using a number of surface and underwater vehicles to rapidly detect and map habitats underwater.



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



Multiple marine vehicle coordination for marine habitat mapping.

So far, the work done at IST/ISR has focused on the problem of **coordinated path following**, whereby 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 PhD student Reza Ghabcheloo (supervised by Profs António Pascoal and Carlos Silvestre) who, for a better understanding of the problem at hand, started by addressing the problem of steering a fleet of wheeled 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. His work provides a solution to these problems using a simple algorithm that builds on linearization techniques and gain scheduling control theory. Using this set-up, path following (in space) and inter-vehicle coordination (in time) are almost decoupled. Path following for each vehicle amounts to reducing a conveniently defined error vector to zero. Vehicle coordination is achieved by adjusting the speed of each of the vehicles along its path, according to information on the position of some of the other vehicles only. *No other information is exchanged among the robots*. The set-up adopted allows for a simple analysis of the resulting coordinated path following control system. Furthermore, it provides guidelines to evaluate the behaviour of the formation as a consequence of certain vehicle failures or loss of inter-vehicle communications. In his attempt to formulate the problem in a more general setting, Reza recently showed how graph theory and nonlinear systems analysis can be brought together to yield coordinated path following controllers that yield global attractivity and capture the underlying structure of the communications network. His future work will aim at simplifying the proof of convergence obtained, obtaining a formal proof of asymptotic stability (convergence and stability in the sense of Lyapunov), considering the case where some of the communication links are not necessarily bidirectional, and studying the impact of communication failures and latency in the measurements.

### T5. Modeling, Parameter Estimation and Identification, and Integrated Plant-Controller Design for Marine Vehicles.

The problem of marine vehicle system design to meet desired performance requirements in the presence of stringent energy constraints is basically unsolved. The difficulty of the problem lies in the fact that the design of the plant and controller should be interwoven, lest a poor mechanical design impose unduly restriction on what can later be achieved with control. Thus the importance of integrated plant-controller design. Similar problems have been addressed in the aeronautics industry, where the reduction of an airplane's weight while preserving its capability to perform desire missions is of paramount importance. Meeting the above objectives for both marine and air vehicles is indeed a challenging problem that has not even been properly formalized yet. Preliminary steps in this direction have been taken in the marine field for the case where the form of the vehicle has been fixed and only the size of the actuators (deflecting surfaces) is allowed to vary (PhD thesis of Prof. Carlos Silvestre). Clearly, one needs to build a long term research plan to tackle and solve the problem posed above. However, in view of the complexity of the problem at hand, it is wise to start by addressing the "simpler" problem of predicting the open loop performance that can be achieved with a marine vehicle, given its geometry and mass distribution.

The above considerations were instrumental in defining a line of research that has received renewed energy during the stay of Prof. Ettore Barros from the Univ. São Paulo, Brasil, at the DSORL. 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 methodology for parameter estimation was automated as part of the work carried out by Havard Bo from the NTNU during his MSc project at the IST/ISR. A paper that summarizes the work done so far was accepted for presentation in a conference.*** 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. These cooperation links will be fully explored once the software package for AUV modeling parameter developed is calibrated by gauging its predictions of hydrodynamic derivatives against actual data available for two or three representative AUVs, published in the literature.

## T6. Multiple Vehicle Mission Control techniques

In a great number of mission scenarios involving cooperation among multiple vehicles 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 are the subject of current intensive research: path following, trajectory tracking, combined path following / trajectory tracking, and coordinated path following.

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.

In our approach to the development of reliable Mission Control Systems for multiple autonomous vehicles we propose to bring the machinery of multiple systems coordination and networked control to bear on the development of a set of Vehicle Primitives that will be enriched as our research unfolds. Particularly relevant will be the study of algorithms to determine when the vehicle should communicate to interchange knowledge about their state in order to minimize energy expenditure and to reduce the data rates involved. The implementation aspects will also be addressed by viewing each vehicle as a node (generalized embedded system) carrying a set of sensor, actuators, and processing units. Finally, notice that in order to fully implement a Vehicle Primitive, a set of sensors and algorithms must be implemented for navigation, guidance, and control. The decision of what sensors and algorithms to use is of course dependent on the particular conditions observed in real-time (for example, what sensors are working adequately, and in this case what algorithm is most appropriate to process the data acquired?). Furthermore, the algorithms implementing a given Vehicle Primitive are also dependent on and should change according to the type of inter-vehicle communication channels available. Finally, a command issued by the Coordinated Mission Control System to execute a given Multi-Vehicle Primitive may in itself bring information about the "quality" of execution of that Primitive, and this will

in turn impose restrictions on the types of sensors and algorithms that will be used to implement it. Thus, at this level, we are confronted with the interaction between time-driven systems and event-driven systems, which gives rise to a *hybrid system*.

With a view towards developing practical solutions for the implementation of Multi-Vehicle Primitives, and in order to accommodate the above mentioned interaction, 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, a Petri Net software application that is proprietary of ISR/IST and allows for mission programming and running in real-time 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. The work done was the basis for the implementation of the Infante autonomous underwater vehicle mission control system, which was again tested at sea in the Azores, in 2004 using a Real Time Distributed Computing Network developed at ISR/IST and installed on-board the vehicle and a support vessel.

# 3. RESEARCH ACTIVITIES

## *3.1 RESEARCH PROJECTS (32)*

This section contains a brief description of the R&D projects in progress at ISR (Lisbon), IST and University of Algarve during 2004, 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: FREE SUB –** AUTONOMOUS UNDERWATER VEHICLE FOR SUBSEA INTERVENTION


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

**Project Coordinator:** Cybernetix Offshore Department, France.

**Project Description:** The " FREESUB " network addresses the exchange of human resources that are essential to the development of autonomous unmanned sub-sea vehicles (AUVs) for remote intervention on fixed underwater structures. The network's goal is to aid mobility of scientific researchers, technology transfer, and dissemination of information. The " FREESUB " network fosters the exchange of young doctoral and post-doctoral researchers among various EU universities and research institutes. The main technical objective of the project is to contribute to the development of general tools that will in the near future allow autonomous vehicles to navigate to target sites with great precision and to carry out intervention tasks on underwater fixed structures.

In 2004, the work of IST/ISR continued to address the issues of Navigation, Guidance, and Control (NGC) of autonomous underwater vehicles (AUVs). In the Summer of 2004, and following a trend established over the past few years, IST/ISR organized an expedition to the Azores with the objective of carrying out tests with the INFANTE AUV at sea, in cooperation with marine scientists from the Department of Oceanography and Fisheries of the Univ. Azores, Horta, Faial. The Young Researcher Alex Peas played an actively role in the tests, actually witnessing the different phases of system design, development, and launching of an AUV at sea. During the tests, Marcus Cardew from the UK (System Technologies), a well known specialist in the area of underwater acoustics, cooperated with IST/ISR on the evaluation of an acoustic modem for communications between the AUV and a support vessel.

**Research Areas:** Navigation, Guidance, and Control of Marine Vehicles
**Laboratories:** Dynamical Systems and Ocean Robotics Lab (DSORL)
**External Partners:** CEA Teleoperation and Robotics Department (F), Democritus University of Thrace (Gr), The Joint Research Centre of the European Commission (I), Instituto Superior Técnico (P), University of Southampton (UK), UKIFREMER (F).
**Initiated:** October 2000
**Conclusion:** October 2004.
**Funding Agency/Classification:** EU, Human Potential Research Training Network No. HPRN-CT-2000-00032
**Documents produced in 2004:** [122]

**Project name:** **MAROV** – MAPPING OF MARINE HABITATS IN THE AZORES USING ROBOTIC VEHICLES (*)


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

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

**Project Description:** This project puts forward the concept of marine habitat mapping using an autonomous surface vehicle (ASV) and an autonomous underwater vehicle (AUV) equipped with acoustic and vision systems. The ASV allows for the mapping of large areas of the seabed (albeit with low resolution) using acoustic sensors. Furthermore, it acts as an interface between the AUV and a support ship. The AUV is used for higher resolution acoustic mapping, ocean data acquisition, and video and photo image taking closer to the seabed. Data obtained by the two vehicles and other complementary "classical" sources (for example, divers or towed systems) can be geo-referenced, analyzed by marine geologists and biologists, and processed to generate composites of benthic ecosystems using a Geographic Information System (GIS). The project brings together marine science and technology. Its purposes is twofold: i) two develop and test advanced systems for navigation, guidance, vehicle control, and coordinated control of multiple marine vehicles, and ii) contributing to the construction of habitat maps in marine reserve areas around the islands of Pico and Faial in the Azores. During the Summer of 2004, a series of tests were carried out in cooperation with the Department of Oceanography and Fisheries of the Univ. Azores, Horta, Faial. During the tests, the performance of control and mission control algorithms developed for the INFANTE AUV was evaluated. Tests were also done to evaluate the performance of an acoustic communication system between the AUV and a support ship.

**Research Areas:** Marine Habitat Mapping Techniques
**Laboratories:** Dynamical Systems and Ocean Robotics Lab (DSORL), VISLAB
*External Partners:* IMAR and Department of Oceanography and Fisheries, Univ. Azores, IGM – Geological Survey of Portugal.
**Initiated:** December 2000
**Conclusion :** November 2004
**Funding Agency/Classification***:* FCT (PT), Programa Dinamizador das Ciências e Tecnologias do Mar (PDCTM)
**Documents produced in 2004:** [19], [45], [117], [121], [124], [125], [151]

♦

**Project name:** **DREAM** – DEVELOPMENT OF A "SEMI-DEEP" ROV FOR SCIENTIFIC APPLICATIONS AND ENVIRONMENTAL MONITORING (*)

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

**Project Coordinator:** IMAR / Laboratório da Guia, Cascais, Portugal.

**Project Description:** The objective of the present project is the development of a **Remotely Operated Vehicle** capable of "semi-deep" intervention (down to the 1000m range) to be used by the Portuguese scientific community in a variety of ocean research missions. Such a vehicle will allow for the investigation of a group of poorly known environments, including the Portuguese continental shelf, where the large majority of national fisheries are deployed, and the upper "levels" of the different canyons that cut into the Portuguese platform and that condition the Portuguese bathial environments to a high extent. "Off the shelf" vehicles can be found, capable of operating down to the proposed depth range, but none with the type of specifications needed for **environmental observation** and **monitoring**, namely in what relates to accurate positioning and work capacity – sensors and probe installation, sampling gear, video signal processing, etc.

The key technical contribution of the project is the enhancement of a basic ROV structure to enable precise vehicle navigation, guidance, and control as well as acoustic and vision data acquisition, pre-processing, and transmission to a support ship. This will enable maneuvering the ROV along pre-determined searching paths without tight human supervision. Furthermore, it will endow scientific end-users with the capability to survey the ocean floor with great precision by acquiring, among other, side-scan, video, and photo images that are accurately time and position tagged, allowing for mapping of the sea-floor. The user is thus relieved from the tedious and often unsuccessful task of trying to achieve precise vehicle control, namely in the presence of sea currents, effectively shifting the focus of the whole operation to scientific data assessment and overall mission control.

Another objective of the project is the possibility of applying a new concept by developing a "modular" vehicle, capable of being reconfigured for different purposes and mission scenarios. Indeed, no vehicle will meet directly the need of different "configuration" levels, enabling its use from different vessels and at a variety of depth ranges – from "shallow" intervention (c.a. 400m) onboard light vessels of "opportunity" to "deep" diving (down to c.a. 1000m) from a dedicated ship – and a quick "response time" to solicitations such as unpredictable environmental phenomena (e.g. submarine eruptions, spills or other accidents).

The proposing team brings together to the core of the project complementary expertises:

i) the technical competence to develop such a vehicle from a brand system (ISR-IST);
ii) the experience of operation of ROV´s in the Portuguese environments (IMAR-LMG, CREMINER); and
iii) the capacity to operate the vehicle at sea under a wide range of different conditions (IH).

This is an important step in the development of collaborative ventures between science and technology, where either of the two components directly depends on the contribution from the other. The concept also opens the possibility of addressing specific needs of end-users, including social concerns, namely relating to natural resources management. During the year of 2004, the project was focused on the development of the hardware for vehicle navigation and mission control. There was a substantial delay in acquiring a basic electro-mechanical frame on which to install the in-house developed systems. An extension of the project is being negotiated.

**Research Areas:** Marine Habitat Mapping Techniques
**Laboratories:** Dynamical Systems and Ocean Robotics Lab (DSORL), VISLAB
**External Partners:** IMAR/Laboratório da GUIA, CREMINER, Faculdade de Ciências da Universidade de Lisboa.
**Initiated:** December 2000
**Conclusion :** November 2004
**Funding Agency/Classification***:* FCT (PT), Programa Dinamizador das Ciências e Tecnologias do Mar (PDCTM)
**Documents produced in 2004:** [4], [45], [121]

♦

**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)

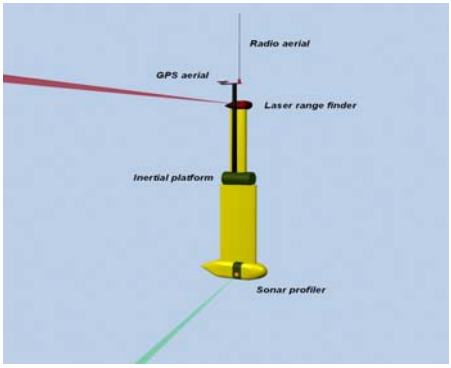
**Project description:** The cost of a rubble-mound breakwater, its expected behavior, as well as the consequences of its failure, do justify the existence of a monitoring programme which helps in the decision making process relative to the timing of the maintenance, or even repair, works. However, the 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 two fold:

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 DELFIM. Within the framework of this project, accurate path following control and navigation systems will be developed in order to guarantee the repeatability of the manoeuvres 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 DELFIM, 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 DELFIM 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 DELFIM. 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. The figure below depicts the concept of the Catamaran DELFIM equipped with the IRIS, during a typical breakwater survey. The figure below 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.



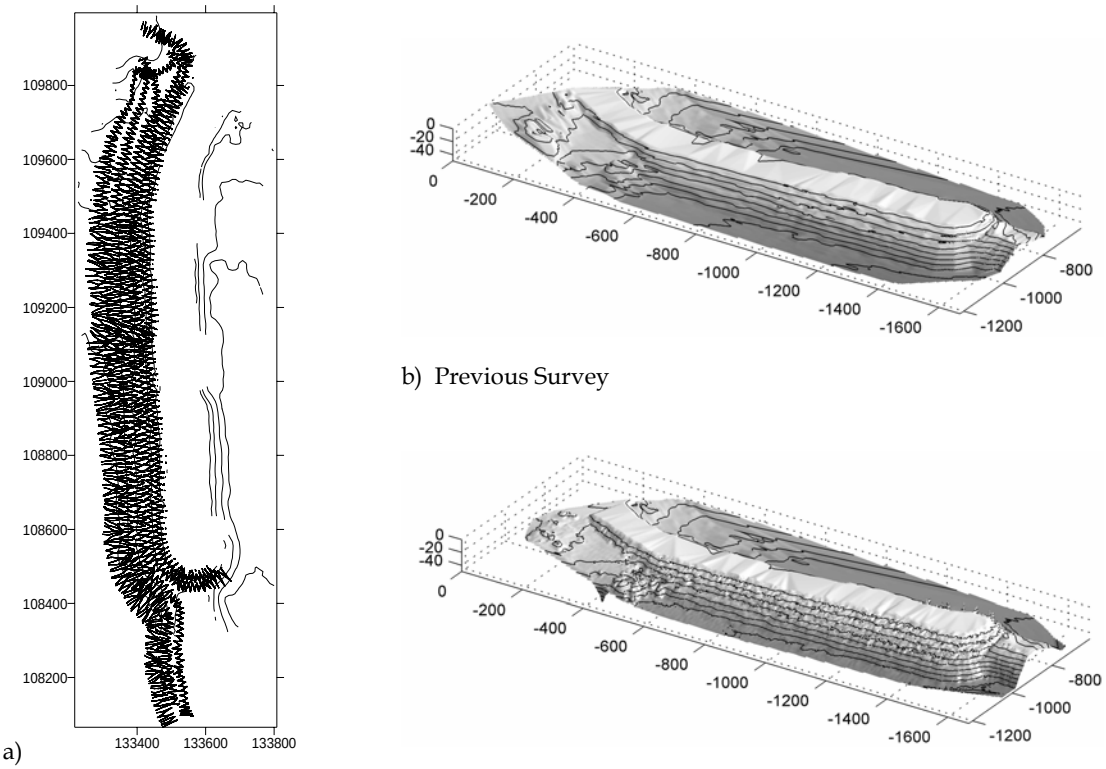

DEFIM and the IRIS tool

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.

The IRIS high accuracy measuring device. Left) Detail of the mechanically scanned high aperture sonar profiler; Right) View of IRIS installed in the support vessel.

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

Figure A 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)

b) Previous Survey

c) IRIS - 2003

Figure A. **a)** Points surveyed with IRIS in 2003; **b)** Perspective of the surface obtained with the points previously surveyed; **c)** Perspective of the surface obtained with points surveyed by IRIS in 2003.

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
**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 2003
**Expected conclusion:** February 2006
**Funding Agency/Classification:** AdI - Agência de Inovação (PT)
**Documents produced in 2004:** [45], [54], [118], [120]

♦

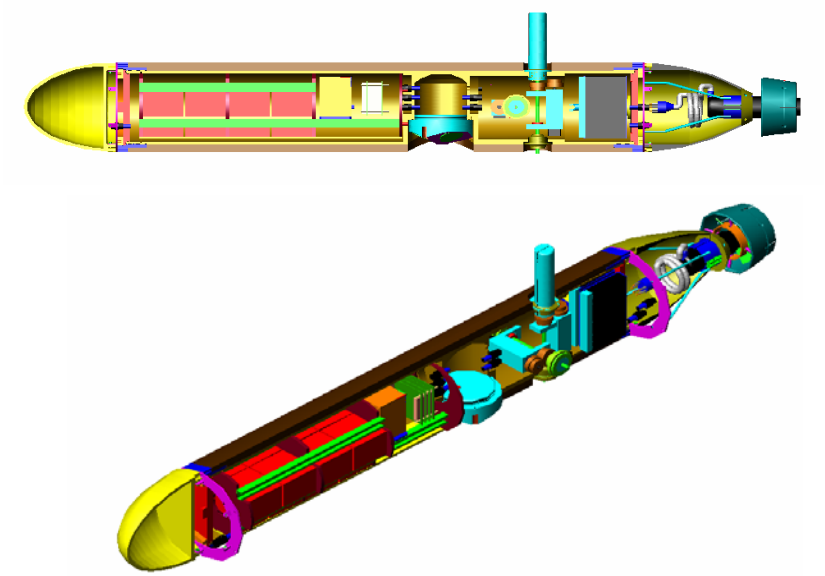
**Project name:** **MAYASub –** DEVELOPMENT OF A SMALL AUV FOR SCIENTIFIC AND COMMERCIAL APPLICATIONS


**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.

The year of 2004 witnessed the design of the systems for navigation, guidance, and control of the MAYA_type AUV. Considerable work was done towards the modelling and estimation of the hydrodynamic parameters of an AUV of this kind. Tests were carried out in the Azores with the objective assessing the performance of the Doppler AUV and the sidescan sonar unit that will equip MAYA. At a mechanical/electrical level, the work carried by the Indian partner NIO in cooperation with IST/ISR and RINAVE led to the design of the hull, energy and propulsion systems for the AUV. The Indian mechanical design will be evaluated during tests at sea. The lessons learned will impact on the design of the final AUV configuration that will be adopted by IST/ISR.



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 2006.
**Funding Agency/Classification:** AdI - Agência de Inovação (PT)
**Documents produced in 2004:** [3], [4], [45], [46], [51], [117], [119], [121], [123], [124], [125], [126], [132], [151]

♦

**Project name:** ABSOLUTE SENSOR AIDED INERTIAL NAVIGATION SYSTEMS

**Project Coordinators:** Prof. Carlos Silvestre & Prof. Paulo Oliveira (ISR / IST)

**Project description:** This project focuses on the design and implementation of inertial navigation systems that must provide, in real time, accurate estimates of the linear and angular positions, and velocities of the autonomous vehicles where they are installed. Micro-Electro-Mechanical Systems (MEMS) are nowadays key technologies to develop Inertial Navigation Systems for autonomous vehicles because of their reduced size, cost and power consumption, relative to conventional devices. Currently off the shelf available MEMS, like rate gyros and accelerometers, are still much less accurate than standard inertial sensors. This requires an extra effort in the development of online compensation techniques involving absolute sensors for biases compensation and platform alignment. The overall goal of this project is to exploit different absolute sensor characteristics, in their natural measurement space, using advanced tightly-coupled architectures to develop MEMS based INS for autonomous vehicles. It is expected to improve the natural INS drifting behaviour resorting to sensors that are currently available in autonomous vehicles. A few cases of interest include:
1) Using state of the art GPS technology, the position of a helicopter can be measured with sub-metric accuracy at low data rate in a pre-specified datum. This accuracy can be achieved using commercially available differential GPS receivers. The Inertial Measuring Unit (IMU) provides accelerations and attitude changes of the platform. The fusion of these data with the linear position available from the GPS receiver produces high update rate accurate position and attitude estimates that are fundamental to stabilize the platform and support the guidance and control system for high precision surveying applications.

2) A laser range finder (LRF) generates highly accurate distance measurements (less than 5 cm), which can be used as an aiding sensor in the take-off, landing phases, or for local navigation close to structures providing estimates of the altitude (distance at the local vertical relative to the ground) and vertical velocity of the helicopter to the specialized navigation systems.
Constraints imposed by the different aiding sensors, like availability and accuracy, require smooth filter switching techniques between different INS compensation techniques.

**Research Areas:** Inertial Navigation Systems (INS), Extended Kalman Filter, Unscented Kalman Filter, Nonlinear Filters, Sensor based INS aiding techniques.
**Laboratories:** DSOR.
**Initiated:** January 2004
**Expected conclusion:** December 2006
**Funding Agency/Classification**: ISR/DSOR Internal Project
**Documents produced in 2004**: [121]

♦

**Project name:** **EXOCET/D** - EXtreme ecosystem studies in the deep OCEan: Technological Development

**Project leader within ISR:** Prof. António Pascoal

**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. The figures below illustrate part of the activity developed during the first year of the project.

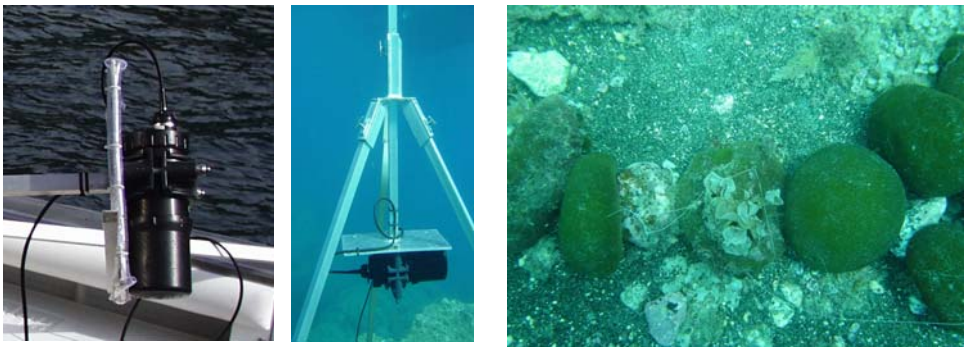


Fig. B.

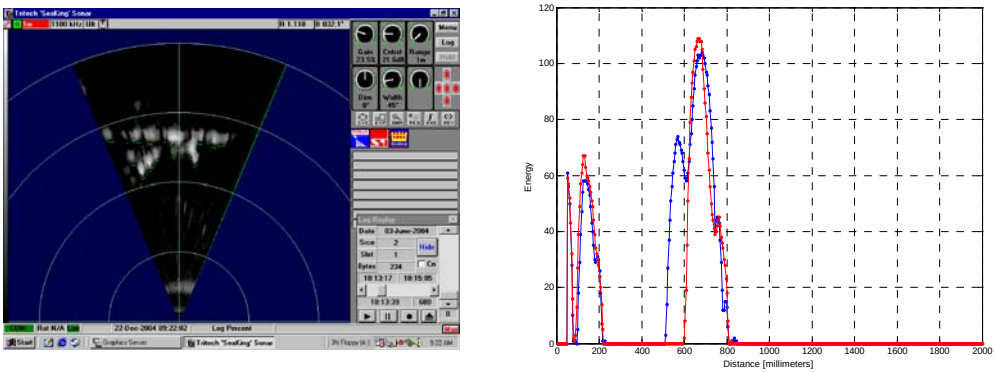



Fig. C

**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.

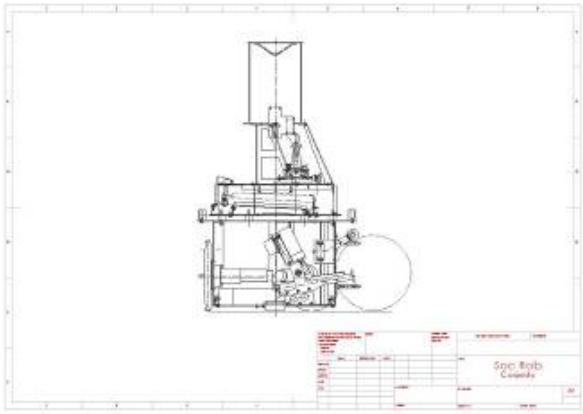
**Research Areas:** Acoustic data acquisition and processing, real time-systems, navigation.
**Laboratories:** DSORLab
**External Partners:** IFREMER (FR), IMAR/DOP/Univ Azores (PT), AWI (GER), UPMC (FR), CNRS (FR), Cardiff University (UK), Heriot-Watt Univ. (UK), U. Algarve (PT), Univ. Bremen (GER), SeeByte (UK), Systea (IT), Capsum Gmbh (GER), and KC-Denmark (DK)
**Initiated:** January 2004
**Expected conclusion:** December 2006
**Funding Agency/Classification**: EU funded project, 6th Framework Programme.
**Documents produced in 2004**: [53], [129], [130], [131]

## 3.1.2 COOPERATIVE ROBOTICS

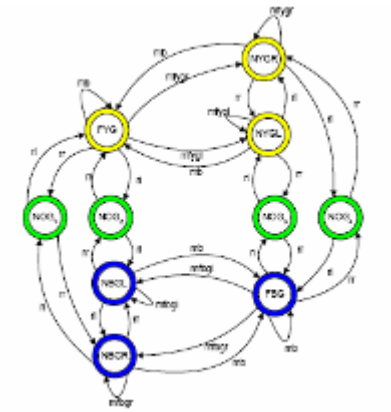
**Project name:** **SocRob** – SOCIETY OF ROBOTS OR SOCCER ROBOTS

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

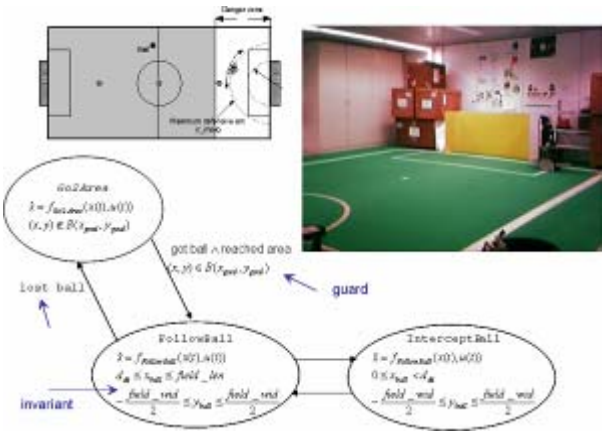
**Project description:** This project fosters general research on multi-agent robotic systems, aiming at introducing methodologies for task planning, task allocation and teamwork supervision/coordination, driven by results from Distributed AI, Hybrid Systems and Discrete Event Systems theory. Its current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



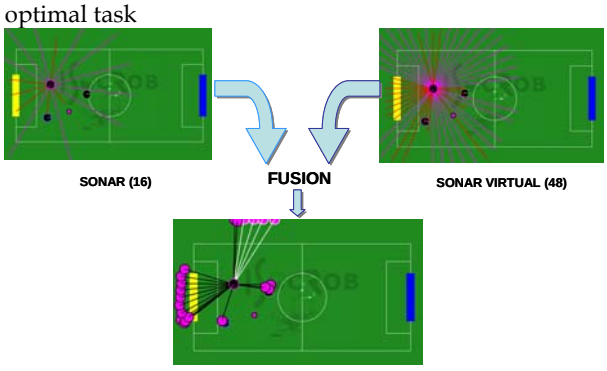
The FCT project started in 2003, and includes the construction of new omnidirectional 3-wheeled robots. The robots include one catadioptric omnidirectional vision system, a sonar ring, one rate-gyro and one optical mouse to improve odometry, as well as an on-board laptop which fosters a plug-and-play type of sensor and actuator connections. Besides being specially designed for robotic soccer (one electromechanical kicker with controllable kick force within a given range) the robots are intended to serve as a comprehensive research platform with an open software and hardware architecture.



Regarding the research conducted in this period, a topological navigation system, based on the description of key-places by a reduced number of parameters that represent images associated to specific locations in configuration space, and its application to robotic soccer, through the implementation of the developed algorithms to RoboCup Middle-Size League robots, was developed. A topological map is associated with a graph, were each node corresponds to a key-place. Using this approach, navigation is reduced to a graph path search. Principal Components Analysis was used to represent key-places from pre-acquired images and to recognize them at navigation time. The method revealed a promising performance navigating between key-places and proved to adapt to different graphs. Furthermore, it leads to a robot programming language based on qualitative descriptions of the target locations in configuration space (e.g., Near Blue Goal with the Goal on its Left).




Discrete-event and hybrid systems based models of soccer robots were also developed, for the purpose of either improving the performance of a robotic goalkeeper through parameter tuning using simulations of the hybrid automaton model, and of obtaining optimal solutions for the problem of finding the sequence of primitive actions that reduce the time up to scoring a goal, effectively determining the optimal task




A method for representing, communicating and fusing distributed, noisy and partial observations of an object by multiple robots was also developed and implemented in robotic team. Each sensor is considered as a team member making decisions locally to achieve a local estimate. The local estimates of a robot are then fused with the other robots local estimates to achieve a global fusion estimate of the objects surrounding the team, creating a more reliable and accurate world model.

**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 since October 2003
**Expected Conclusion:** undefined (FCT project: June 2005)
**Funding Agency/Classification:** FCT (PT), POSI/ROBO/43900/2002
**Documents produced in 2004:** [12], [13], [22], [57], [60]

♦

**Project name:** **RESCUE –** COOPERATIVE NAVIGATION FOR RESCUE ROBOTS

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

**Project description:** This project fosters research on multi-agent robotic systems for search and rescue operations as its long-term goal. The project is focused on obtaining new results on outdoors perception and navigation, both for individual and cooperative robots.
In this period, the work focused on topological navigation of the ATRV-Jr land robot comprising the construction of a topologic map supported on features extracted and selected from raw data acquired with a video camera and a laser scanner, a module of topological localization and the selection of a path in the topological map aiming at optimizing a given criteria.
Other work within the project concerned the usage of discrete event systems to model the navigation of a homogeneous population of mobile robots moving in an environment composed of a number of discrete sites. Results that relate the blocking and controllability properties of the automaton modeling the complete system with the blocking and controllability properties of the smaller dimension automata modeling each robot navigating in the environment were derived.
An agent-based software architecture that intends to close the gap between hybrid systems and software agent architectures was conceived and partially implemented. The developed concepts and tools provide support for: task design, task planning, task execution, task coordination and task analysis for a multi- robot system.

**Research Areas:** Distributed Continual Planning, Robotic Task Coordination, Cooperative Navigation, Cooperative Perception, Vision-Based Topological Mapping.
**Laboratories:** Intelligent Systems Lab, Vision Lab, Mobile Robotics Lab
**External Partners:**
**Initiated:** November 2000
**Conclusion:** October 2004
**Funding Agency/Classification:** FCT (PT), SRI/32546/99-00
**Documents produced in 2004:** [58], [59], [69], [79], [81], [134], [137], [140]

♦

**Project name:** **SACOR –** SEMI-AUTONOMOUS COOPERATIVE ROBOTS

**Project leader within ISR:** Prof. João 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) using Viability Theory; (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 the relevant issues in viability theory 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.

**Research Areas:** Cooperation of robotic devices
**Laboratories:** Mobile Robotics Lab
**External Partners:**
**Initiated:** September 2002
**Conclusion:** September 2005
**Funding Agency/Classification:** FCT(PT), POSI/SRI/40999/2001
**Documents produced in 2004:** [75], [76], [77], [80]

♦

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

**Project leader:** IdMind, Engenharia de Sistemas, Lda

**Project description:** This project aims at building 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 will be 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 will be semi-autonomous, i.e., it will be tele-operated from a remote station but will simultaneously display the capacity to carry out short tasks autonomously. The robot will execute commands sent by a team of SAR experts, located in a safe place. During task execution, the robot will relay 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 will be a small size, low weight, robust to collisions, dust and water infiltration vehicle.

**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
**Expected Conclusion:** March 2005
**Funding Agency/Classification:** Agência de Inovação, AdI(PT), Consortium Projects
**Documents produced in 2004:** [142], [143]

### 3.1.3 IMAGE PROCESSING

**Project name:** **HEART 3D** - MEASUREMENT OF THE HEART GEOMETRY FROM ULTRASOUND IMAGES

**Project Leader within ISR:** Prof. Jorge Salvador Marques (IST/ISR)

**Project Description:** This project studies heart diagnosis tools based on 3D ultrasound techniques. The project has three main goals: i) the development of image reconstruction and heart measurement algorithms for the analysis of the cardiac cycle and computation of clinical parameters (ventricular volume, ejection fraction and wall thickness); ii) implementation of an experimental set up for the acquisition of 3D data during medical examinations of the heart and iii) clinical evaluation of the 3D ultrasound algorithms developed in the project Bayesian reconstruction methods will be used to estimate a 3D+T model of the heart at different instants of the cardiac cycle. The region of interest will be described using a multi-scale representation based on 3D splines. The motion and deformation of the heart cavities will be obtained by segmenting the reconstructed volume at each instant of time. To fill the gaps between the inspection planes some kind of interpolation has to be devised. This operation is embodied in the Bayesian reconstruction provided that an adequate prior is used. Unfortunately popular Gaussian priors have an undesirable smoothing effect at the boundaries, which degrades the estimation of the heart walls. Therefore, a discontinuity preserving prior will be used instead. Another key aspect for achieving high quality results concerns the data model used for reconstruction.

**Research Areas:** medical imaging, image processing, image reconstruction, noise removal
**Laboratories:** Signal Processing Lab.
**External Partners:** Cardiology Department of Hospital de Santa Maria, University of Aveiro
**Initiated:** 2000
**Expected Conclusion:** 2004
**Funding Agency/Classification:** FCT (PT) - POSI/33726/CPS/2000
**Documents produced in 2004:**

♦

**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
**Expected Conclusion:** 2005
**Funding Agency/Classification:** FCT (PT) - POSI/ CPS / 37844 / 2001
**Documents produced in 2004:**

**Project name:** **AMA**- AUTOMATIC MODELING 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:** video processing
**Laboratories:** Signal Processing Lab.
**External Partners:**
**Initiated:** 2002
**Expected Conclusion:** 2005
**Funding Agency/Classification:** FCT(PT) - POSI/SRI/41561/2001
**Documents produced in 2004**: [5], [17], [84], [85], [161], [163]

## 3.1.4 UNDERWATER ACOUSTICS

**Project name:** **ATOMS** - ACOUSTIC TOMOGRAPHY MONITORING SYSTEM

**Project Leader within ISR:** Prof. Sérgio M. Jesus

**Project Description:** The ATOMS project aims at developing an integrated system for large-scale ocean monitoring, using acoustic tomography. In order to demonstrate the feasibility of the approach, an experimental test will be performed to characterize the upwelling filament structure off the Cape São Vicente.

**Objectives:**

1- To study the feasibility of a tomographic acoustic network to monitor the entire Portuguese EEZ. That network will be composed of 4/5 acoustic emitters/receivers located in the Azores, continental Portugal and Goringe bank and/or Madeira island. The modeled network will use archived data of temperature/salinity profiles (from NODC and BODC data bases). The main characteristics of the network will be determined in order to achieve a given performance in terms of temperature and current resolution.
2- To develop an integrated system for Ocean Acoustic Tomography (OAT) and perform a test at sea.
3- To develop a preliminary application of the integrated system to monitor a particular area off the Portuguese EEZ. The test target will be the Cape São Vicente filament area, which is one of the most developed and recurrent filaments observed and has important implications in the biological and chemical exchanges between the coastal and offshore ocean.

**Research Areas:** ocean acoustic tomography/environmental monitoring
**Laboratories:** SiPLAB
**External Partners:** CINTAL, EST (UALG), CIMA, IH
**Initiated:** October 2000
**Expected Conclusion:** December 2004
**Funding Agency/Classification:** FCT (PT) **-** PDCTM/P/MAR/15296/1999
**Documents produced in 2004:** [40], [101], [102], [104]

♦

**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:**

1- 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;
2- 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;
3- 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 Processing Lab
**External Partners:** CINTAL, IH
**Initiated:** January 2004
**Expected Conclusion:** December 2006
**Funding Agency/Classification:** FCT(PT) - POSI/CPS/47824/2002
**Documents produced in 2004:** [103], [158]

♦

**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 Processing Lab
**External Partners:** CINTAL, NURC, ULB, RNLNC, IH
**Initiated:** January 2004
**Expected Conclusion:** December 2006
**Funding Agency/Classification:**
**Documents produced in 2004:** [101], [102], [105], [106]

♦

**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.

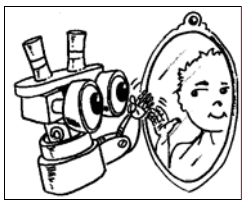
**Objectives:**

1- data-oriented segmentation and inversion algorithms for range-dependent, geoacoustic mapping and seabed characterization;
2- 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;
3- integration of on-site simultaneously measured oceanographic data as apriori information to constrain the tomographic inversion;
4- investigation of stochastic approaches to the signal processing and propagation modeling supporting the inversion of broadband acoustic signals.
5- study of sensitivity to bottom parameters and robustness against oceanographic and acoustic variability using existing SACLANTCEN datasets collected under diverse conditions;
6- 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 Processing Lab
**External Partners:** IH
**Initiated:** October 2004
**Expected Conclusion:** September 2007
**Funding Agency/Classification:**
**Documents produced in 2004:**

## 3.1.5 COMPUTER VISION

**Project name:** **MIRROR –** MIRROR NEURONS FOR RECOGNITION



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

**Project Description:** The goals of MIRROR are: 1) to realize an artificial system that learns to communicate with humans by means of body gestures and 2) to study the mechanisms used by the brain to learn and represent gestures. The biological base is the existence in primates's premotor cortex of a motor resonant system, called mirror neurons, activated both during execution of goal directed actions and during observation of similar actions performed by others. This unified representation may subserve the learning of goal directed actions during development and the recognition of motor acts, when visually perceived. In MIRROR we investigate this ontogenetic pathway in two ways: 1) by realizing a system that learns to move AND to understand movements on the basis of the visually perceived motion and the associated motor commands and 2) by correlated electrophysiological experiments.

**Research Areas:** Computer Vision
**Laboratories:** Vislab - Computer Vision Lab
**External Partners:** DIST - University of Genova (I), University of Ferrara (I), Dept. of Psychology University of Umea, (SE).
**Initiated:** September 2001
**Expected conclusion:** September 2004
**Funding Agency/Classification:** EU-FET-2000-28159
**Documents produced in 2004:** [67], [74]

♦

**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:** Sept. 2002
**Expected conclusion:** August 2005
**Funding Agency/Classification:** POSI/SRI/41506/2001
**Documents produced in 2004:** [68]

**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.

**Research Areas:** Computer Vision
**Laboratories:** Vislab - Computer Vision Lab
**External Partners:** University of Edimburgh (UK), INRIA (F)
**Initiated:** October 2002
**Expected conclusion:** September 2005
**Funding Agency/Classification:** EU, IST-2001-37540
**Documents produced in 2004:** [73]

♦

**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.

**Research Areas:** Intelligent Transportation Systems, Computer Vision
**Laboratories:** Vislab - Computer Vision Lab
**External Partners:** Observit, Tecnologias de Visão por Computador, Lda; Brisa, Auto-estradas de Portugal, SA; AITEK, SRL (Italy)
**Initiated:** September 2003
**Expected conclusion:** October 2005
**Funding Agency/Classification:** FCT(PT) - POSI, Medida 1.3
**Documents produced in 2004:** [70], [71], [72]

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


**Project Leaders within ISR:** Profs. José Santos–Victor and 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.

**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
**Funding Agency/Classification:** EU, IST-2004-004370
**Documents produced in 2004:** [164]

♦

**Project name:** **Dig3D –** SISTEMA ÓPTICO DE DIGITALIZAÇÃO TRIDIMENSIONAL PARA A INDÚSTRIA DOS MOLDES (*)

**Project leader within ISR:** Prof. João Paulo Costeira (IST/ISR)

**Project description:** This project aims the development of an optical three-dimensional scanning system, design to respond to the needs of the mould industry.
Three-dimensional scanning is used for industrial dimensional control and reverse engineering. However, most of the automated systems available (either optical or laser) require too much intervention of a CAD operator during the process of reverse engineering, since they return nonparametric primitives that do not convey topologic information. On the other hand, contact systems require a bigger involvement of human resources during the digitalization stage.
The optical system to be developed will present innovative features that will allow 3D models to include topological information, that will be most useful to the CAD engineer. The system will become a production good of great value to the involved company, since it will lead to the optimization of a significant part of its productive system (industrial design and metrology) wherever it is supported by reverse engineering and automated measuring tasks.

**Research Areas:** Computer Vision, Computer Graphics
**Laboratories:** Vislab
**External Partners:** SET SA, Reverse Eng. SA
**Initiated:** December 2002

**Expected Conclusion:** September 2004
**Funding Agency/Classification:** Agência de Inovação, AdI(PT) – Consortium Projects
**Documents produced in 2004:**

♦

**Project name:** **VirtualScan** - OBJECTOS REAIS EM CONTEÚDOS MULTIMÉDIA

**Project Leader within ISR:** Prof. João Paulo Costeira (IST/ISR)

**Project Coordinator:** Reverse Eng. S.A., Portugal.

**Project Description:** This project aims the development and validation of methodologies designed to automate the generation of appealing three-dimensional graphical contents. These methodologies will be integrated within a single multimedia tool, that will be able to (1) generate 3D models by digitizing real object, (2) optimize their visual appearance, (3) map the registered textures and colors onto the resulting geometric models and (4) generate rendering and manipulation code that can be inserted in standard multimedia software.
The results of this project will be used in the construction of an innovative production good, which will optimize the full process of graphical content design for the Internet, cd-rom and interactive TV. This optimization represents a major improvement of the products and services offered by the Companies in this consortium.
Target-customers for such a tool are mainly companies that develop multimedia contents for e-commerce and virtual catalogs (commercial and cultural), computer-game industry, visual-effects and animation.
This project will promote a future technological and commercial partnership between the Companies. The consortium also intends to give international visibility to this project and to actively search for international partners for future technological and commercial cooperation.

**Research Areas:** Computer Vision, Computer Graphics
**Laboratories:** Vislab
**External Partners:** SET SA, Reverse Eng. SA
**Initiated:** December 2003
**Expected Conclusion:** December 2004
**Funding Agency/Classification:** Agência de Inovação, AdI(PT) – Consortium Projects
**Documents produced in 2004:**

## 3.1.6 ARTIFICIAL INTELLIGENCE

**Project name:** **MS-AGENCY:** CONTROL OF MANUFACTURING SYSTEMS USING SOCIETIES OF EVOLUTIVE AGENTS

**Project Leader within ISR:** Prof. Luís Custódio (IST/ISR)

**Project Description:** In this project, the problems raised by the development, utilization and implementation of both hierarchical and heterarchical control architectures for manufacturing systems (MS) are studied and identified. The goal is to develop a hybrid control architecture where the lower levels are implemented through a heterarchical structure, using a new paradigm of distributed (knowledge) representation called "Societies of Agents". The upper levels are structured into a hierarchy where the top levels provide orders for bottom levels, as usual. In terms of equipment and layout it is assumed that the shop-floor is (physical or virtually) divided into a set of manufacturing cells, each one capable of producing a predefined set of products. Each cell is represented by a single agent, which is capable of interacting within a society of similar agents.

**Research Areas:** Artificial Intelligence, Multi-agent Systems, Manufacturing Systems Control
**Laboratories:** Intelligent Systems Lab
**External Partners:**

**Initiated:** August 2001
**Expected conclusion:** May 2004
**Funding Agency/Classification:** FCT(PT) - POSI/P/EEI/12175/1998
**Documents produced in 2004:** [8], [61], [62], [111], [112]

♦

**Project name:** **DARE –** DEVELOPMENT OF EMOTION-BASED ROBOTIC AGENTS

**Project Leader within ISR:** Prof. Luís Custódio (IST/ISR)

**Project Description:** The aim of this project is the study and development of methodologies and tools necessary to implement emotional robotics agents capable of dealing with unstructured and dynamic environments. Therefore, the goal is not the optimization of some particular ability, but instead the research focus is put on general competence to learn, adapt itself and survive. In order to practically test these ideas, a small autonomous robot will be adapted and used based on technology already developed and tested.

**Research Areas:** Artificial Intelligence, Emotion-based Agents
**Laboratories:** Intelligent Systems Lab
**External Partners:**
**Initiated:** August 2001
**Expected conclusion:** May 2004
**Funding Agency/Classification:** FCT(PT) - POSI/P/EEI/12184/1998
**Documents produced in 2004:** [64]

## 3.1.7 COMMUNICATIONS

**Project name:** CHANNEL ESTIMATION FOR EQUALIZATION AND SYNCHRONIZATION IN OFDM UNDERWATER ACOUSTIC COMMUNICATIONS SYSTEMS

**Project Leader within ISR:** Prof. Victor Barroso (IST/ISR)

**Project Description:** Digital communication using acoustic modems is the method of choice for exchanging data among distant or highly mobile equipment used in various underwater activities. However, achieving efficient communication in this environment is challenging due to severe distortions that affect the transmitted signals as they undergo multiple reflections and refractions in their propagation path. Attempts to overcome these impairments in high data rate coherent modems haven't been entirely satisfactory, thus hampering their widespread adoption.

Recently, much attention has been devoted to the use of OFDM (Orthogonal Frequency Division Multiplexing) modulation for wireless and cable applications as a way of approaching channel capacity with simple transmitter/receiver architectures. In OFDM the message stream is divided into many parallel lower rate streams that modulate a set of partially overlapping orthogonal carriers. Since longer symbols are less sensitive to multipath, equalization requirements may be considerably relaxed on each sub carrier. This feature is quite appealing in underwater communications, where highly complex filters used for equalization constitute the main computational bottleneck.

Although preliminary studies on the use of OFDM for underwater coherent communication have been published, the analyses are rather superficial and should mainly be regarded as proof of concept. The present proposal will address issues that are particularly relevant in an underwater environment:

1- Channel identification and equalization are extremely important in underwater communication because multipath propagation may induce channel responses lasting hundreds of milliseconds. Unlike terrestrial OFDM

applications, frequency-selective channels have to be explicitly considered. Recently developed blind or semi-blind identification techniques should be applicable under such conditions, thus reducing the need for pilot tones.

2- Significant Doppler shift may be induced in acoustic waveforms even by relatively slow emitter/transmitter motion caused by waves and currents. Performance studies for terrestrial OFDM have shown that accurate tracking of average Doppler is required to ensure low intercarrier interference. Average and differential Doppler compensation has not been studied in detail for single-carrier communications, but it will likely play an important role in underwater OFDM systems. An approach based on simple ray propagation models will be used to predict the evolution of Doppler in each path and guide the tracking algorithms.

**Research Areas:** Statistical Signal Processing
**Laboratories:** Signal Processing Lab.
**External Partners:**
**Initiated:** 2000
**Expected Conclusion:** April 2004
**Funding Agency/Classification:** FCT(PT) - POSI/33205/CPS/2000
**Documents produced in 2004:** [96], [97]

♦

**Project name:** MODEM FOR DIGITAL COMMUNICATION IN UNDERWATER ACOUSTIC CHANNELS

**Project Leader within ISR:** Prof. Victor Barroso (IST/ISR)

**Project Description:** The goal of this project is to develop a prototype modem for underwater acoustic communication that will serve as a testbed to evaluate signal processing algorithms for severely distortive channels. The design is centered around a general computational platform based on a Digital Signal Processor, and includes electronics for transducer interfacing and I/O management. Mechanical aspects related to encapsulation of the ensemble are also considered. Software provides the basic functionality needed to synchronize, frame and code data, but most of the effort is devoted to equalization algorithm design and implementation, which is a key component needed to compensate for the distortion introduced by the transmission medium.

**Research Areas:** Digital Signal Processing, Communications
**Laboratories:** Signal Processing Lab.
**External Partners:**
**Initiated:** May 2001
**Expected Conclusion:** April 2004
**Funding Agency/Classification:** Ministério da Defesa – Fundação das Universidades Portuguesas
**Documents produced in 2004:**

♦

**Project name:** **GEODIF –** DIFFERENTIAL GEOMETRY BASED SIGNAL PROCESSING TECHNIQUES FOR THE RESOLUTION OF CONVOLUTIVE MIXTURES IN WIRELESS COMMUNICATIONS SYSTEMS

**Project Leader within ISR:** Prof. Victor Barroso (IST/ISR)

**Project Description:** The spatial division multiple access (SDMA) concept for mobile radio cellular systems has recently attracted much attention. SDMA is a spectral bandwidth – saving multiple access technique which provides increased cellular capacity via effective exploitation of the spatial dimension of the radio resource. In SDMA – based wireless networks, several users within the same cell share the same time – frequency channel, as opposed to the other popular multiple access methodologies, e.g., time division multiple access (TDMA) or

frequency division multiple access (FDMA), where each channel is occupied at most by one user at a time. This efficient spectral allocation strategy per cell permits to expand the overall capacity of current cellular infrastructures, without consuming additional radio frequency (RF) bandwidth. From the receiver viewpoint, the SDMA technique raises a new signal processing problem: in addition to suppression of the intersymbol interference (ISI) induced by multipath propagation, the SDMA receiver has to separate the linearly superimposed users. Current research on SDMA architectures focus on developing algorithms capable of resolving linear convolutive mixtures of digital sources. The main goal of this proposal is the optimal design of SDMA receivers based on differential-geometric tools. Here, optimality results from the full exploitation of the data model, with possible incorporation of prior knowledge (Bayesian processing).
In fact, spatial and/or temporal over sampling is the preferred data acquisition scheme in SDMA receivers, and leads to highly structured baseband data matrices. In general, these can be written as the product of a block Hankel channel matrix and a block Toeplitz signal matrix, embedded in (usually Gaussian) additive noise. Also, the entries of the signal matrix are restricted to a finite alphabet, dictated by the chosen linear digital modulation format. In the majority of current approaches, this information is only partially exploited so that they are sub optimal in that respect. Moreover, by exploiting 2nd order statistic, further structure can be incorporated into the problem, as the channel matrix can be turned unitary. In this proposal, we aim at designing maximum-likelihood (ML) estimators of the mixing channel matrix and/or of the emitted data sequences, which respect all the known algebraic restrictions. By fully matching the estimators to the data model constraints, a significant improvement of their performance can be expected. The constrained ML estimators are to be derived in a differential geometry framework. This viewpoint has recently proven to be successful in solving some other relevant signal processing problems, e.g., direction-of-arrival (DOA) estimation, denoising of corrupted Hankel matrices, and adaptive subspace tracking. For the structured ML estimation problem at hand, manifold theory seems to be the most natural setting, as the algebraic restrictions on the parameters can be efficiently expressed as Cartesian products of certain differentiable manifolds (Lie groups orthogonal matrices, linear varieties of Hankel matrices, etc.). Optimization of the constrained likelihood function is to be achieved by developing techniques of optimization over differentiable manifolds. This implies a detailed characterization of the constraint differentiable surfaces (tangent spaces, curvature, etc.), which also provides the appropriate tools to study the convergence properties of the class of algorithms to be derived.

**Research Areas:** Statistical Signal Processing, Communications
**Laboratories:** Signal Processing Lab.
**External Partners:**
**Initiated:** January 2002
**Conclusion:** December 2004
**Funding Agency/Classification:** FCT(PT) - POSI/38775/CPS/2001
**Documents produced in 2004:** [27], [94], [95]

## 3.1.8 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:** Presently, some Unmanned Air Vehicles (UAVs) exhibit a high degree of reliability in operation in the presence of dynamic and uncertain environments and challenging operating scenarios. Among the many UAV configurations available today, helicopters are one of the most manoeuvrable 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 manoeuvrable 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 those 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: Develop 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. A first laser based terrain following controller was designed and evaluated in simulation.

- Path following controllers for extended flight envelope manoeuvres: This topic addressed the study control strategies to drive the helicopter along arbitrary paths in 3D, Namely paths that can involve sudden changes on the platform angle of attack (e.g. 0 to 90 degrees). The theoretical tools required to address these problems borrow from nonlinear scheduled control theory.

- Real time distributed architectures for mission and vehicle control. This topic involved the study and development architectures to simplify the task of performing the concerted operation of the different systems resident on board autonomous vehicles.

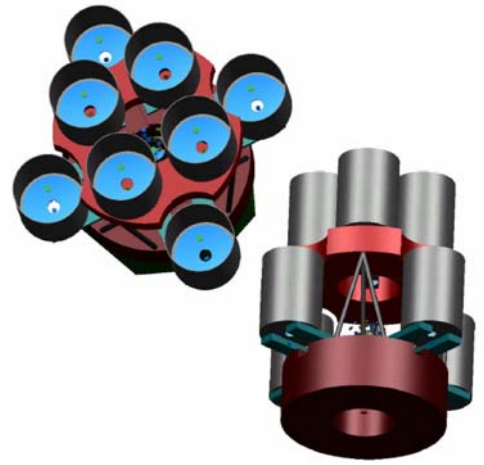
The Vario Xtreme Helicopter equipped with control electronics. Left: Helicopter ready to takeoff; Right: Detail of the control electronics and motion sensors.

The figure shows the Vario Xtreme model scale Helicopter during the tests in May 2004. These open loop tests with on-board instrumentation were carried for flight test data acquisition to calibrate the helicopter dynamic simulator.

**Research Areas:** Nonlinear dynamic modelling, Guidance and Control, Inertial Navigation, laser and vision mapping.
**Laboratories:** DSOR, VISLAB
**External Partners:** Instituto Geológico e Mineiro, Lisbon, Portugal
**Initiated:** May 2002
**Expected conclusion:** April 2005
**Funding Agency/Classification:** FCT(PT) - POSI/SRI/41938/2001
**Documents produced in 2004:** [55], [120], [128]

## 3.1.9 SPACE APPLICATIONS

**Project name:** HIGH RESOLUTION OPTICAL SATELLITE SENSORS



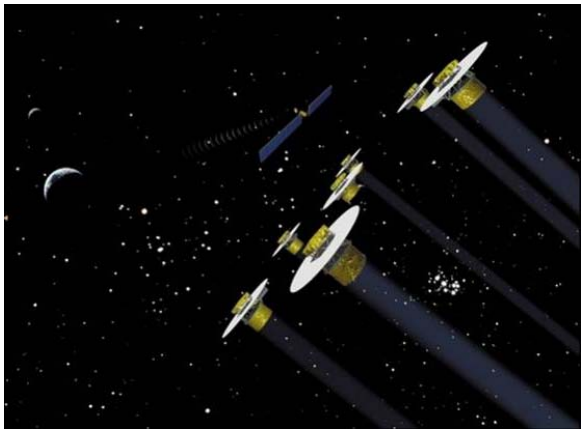
**Project Leader:** Alenia Spazio (Italy)

**Project Description:** The main objective of this project is to develop a High Resolution Optical Satellite Sensor 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. ISR participation concerns the internal closed loop control of relative mirror positions, so as to calibrate the system, using interferometry-based techniques.
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
**Expected Conclusion:** May 2005
**Funding Agency/Classification:** EUCLID - RTP 9.09
**Documents produced in 2004:**

♦

**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 study will be 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. Decentralized solutions seem to be the most promising approach, as they do not depend on a communications link and/or on a central spacecraft. As such, this work will devote more attention to solutions where both estimation and control can be computed locally at each spacecraft and thus depend solely on relative measurements, feasible at each spacecraft. Nevertheless, centralized/distributed

approaches will be covered as well, and issues such as robustness in the presence of temporary occlusion or permanent failure of sensors and communications, as well as the minimization of information flow will arise.

**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 2005
**Funding Agency/Classification:** ESA (European Space Agency) 17529/03/NL/LvH/bj
**Documents produced in 2004:** [135], [136]

## *3.2 POST-DOCS ACTIVITIES REPORTS*

### 3.2.1 Activity report of DAN DIMITRIU

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

[A] **Pedro Lima, Dan Dumitriu, Sónia Marques**, "Candidate Formation Algorithms Simulation Results and Performance Assessment", TN4-FEMDS-8Nov2004.

[B] **Pedro Lima, Dan Dumitriu, Sónia Marques**, "Candidate Estimation, Guidance and Control Algorithms Functional Design and Analysis", TN3-FEMDS-29Sep2004.

### 3.2.2 Activity report of ETTORE BARROS

**Period:** January 2004 to June 2004

My post-doctoral research work at the DSORL is funded by CAPES of Brasil, during my leave from the University of São Paulo, where I am a member of the teaching staff of the Department of Mechatronics. My final semester at ISR, during the first half of 2004, was aimed at cementing the work plan on AUV Modeling and Parameter Estimation, which is briefly summarized below

**Research Topic:**

**MODELING, PARAMETER ESTIMATION, AND COMBINED PLANT-CONTROLLER OPTIMIZATION OF AUTONOMOUS UNDERWATER VEHICLES (AUVs)**

**Objective :**

My work program at DSORL addresses the general problem of autonomous *underwater vehicle (AUV) modeling 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.

Methods for parameter estimation based on the geometry of a marine vehicle and its mass distribution properties have been used for decades in the ship building industry. Important steps have also been taken in order to adapt parameter estimation methods, originated in the aeronautical science, to the prediction of submarine and AUV dynamics [1]. Recently, spawned by the widespread availability of powerful computers, there has been a surge of interest in applying Computational Fluid Dynamics (CFD) methods to the prediction of stability derivatives for marine vehicles [2]. However, to the best of my knowledge there is not, in the literature available, an evaluation and validation of these methods concerning AUV applications. In fact, there seems to be lacking an established approach for AUV parameter estimation that would allow for the computation of the associated modelling errors.

The short term goal of my research effort is to bring together different techniques for AUV parameter estimation that include analytical and semi-empirical methods (ASE) and to use them to predict the hydrodynamic derivatives of a large class of AUVs with conventional, streamlined bodies, in the vertical (dive) and horizontal planes. The long term plan is to complement these approaches with CFD techniques and to evaluate the accuracy of the different parameter estimation methods through a restricted number of tests with reduced or full scale vehicles in hydrodynamic tanks or at sea, respectively. These goals will be pursued in cooperation 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 with whom collaborative research programs have been established. 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. In a more general setting, the work proposed aims to contribute to the development of computational methods for combined plant/controller optimization, that is, for the combined design of AUVs and controllers for increased performance at sea. Previous work in this area can be found in [3].

**Bibliography:**


[1] **H. Bohlmann**, Berechnung Hydrodynamischer Koeffizienten von Ubooten zur Vohrhersage des Bewegungsverhaltens", PhD Thesis, Institut fur Schifbau der Universitat Hamburg, 1990.

[2] **D. Humphreys**, "Correlation and Validation of a CFD Based Hydrodynamic and Dynamic Model for a Towed Underwater Vehicle", Proc. OCEANS'01 Conference, USA, 2001.

[3] **C. Silvestre**, "MultiObjective Optimization Theory with Applications to the Integrated Design of Controllers/Plants for Underwater Vehicles", PhD Thesis, Instituto Superior Técnico, Lisbon, 2000.


**Major Results :**

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 methodology for parameter estimation was automated as part of the work carried out by Havard Bo from the NTNU during his MSc project at the IST/ISR [A], [B]. A paper that summarizes the work done so far was accepted for presentation in a conference [C].*** Future work will push the development of new methodologies for combined plant/controller optimization.

**Documents:**


[A] **Havard Bo**, "Hydrodynamic Estimation and Identification", Department of Engineering Cybernetics/ NTNU, Trondheim, Norway and Instituto Superior Técnico /ISR , Lisbon, Portugal, August 2004.

[B] **E. Barros, A. Pascoal**, "Estimation of the Hydrodynamic Derivatives of the MAYA-AUV using Analytical and Semi-Empirical Methods", DSORL-ISR Technical Report, August 2004.

[C] **E. Barros, A. Pascoal, E. De Sa**, "AUV Dynamics: Modelling and Parameter Estimation Using Analytical, Semi Empirical, and CFD Methods," *Proc. IFAC Conference on Control Applications in Marine Systems,* Ancona, Italy, July 7-9, 2004.

### 3.2.3 Activity report of JACINTO NASCIMENTO

**Period**: September 2003 to December 2004

**Fellowship**: LTT project, *Long Term Tracking of Multiple Objects for Surveillance* (POSI/CPS/37844/2001); 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). The main goal of my research is strongly related with the objectives of the following two projects which are briefly summarized bellow.

**Research topic**:

**HUMAN ACTIVITY RECOGNITION AND MODELLING**

**Objective 1** (LTT project):

**LTT**, *Long Term Tracking of Multiple Objects for Surveillance* (POSI/CPS/37844/2001).

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 labeling scenarios. The tracking algorithms will be applied in the context of urban surveillance.

**Objective 2** (CAVIAR project):

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

The central research question in CAVIAR is : *Can rich local image descriptions from foveal and other image sensors, selected by a hierarchal visual attention process and guided and processed using task, scene, function and object contextual knowledge improve image-based recognition processes?*

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:

**Published papers**:

[A] **J. Nascimento, J. S. Marques**, "Performance evaluation of object detection algorithms for video surveillance", *IEEE Transactions on Multimedia* 2004, (accepted).

[B] **J. Nascimento, J. S. Marques**, "New performance evaluation metrics for object detection algorithms", *PETS ECCV, 6th International Workshop on Performance Evaluation for Tracking and Surveillance*, pp. 7-14, Prague, Czech Republic, May 2004.

**Submitted papers**:

[C] **J. C. Nascimento, M. A. T. Figueiredo, J. S. Marques**, "Segmentation and classification of human activities". Submitted to *British Machine Vision Conf., Int. Workshop on Human Activity Recognition and Modeling - HAREM 2005*.

[D] **D. Hall, J. Nascimento, P. Ribeiro, E. Andrade, P. Moreno, S. Pesnel, T. List, R. Emonet, B. Fisher, J. Victor, J. Crowley**, "Comparison of target detection algorithms using adaptive background models". Submitted to the *2nd Joint IEEE Int. Workshop of the ICCV 2005 on Visual Surveillance and Performance Evaluation of Tracking and Surveillance (VS-PETS)*.

[E] **J. C. Nascimento, M. A. T. Figueiredo, J. S. Marques**, "Recognition of human activities using space dependent switched dynamical systems". Submitted to *IEEE Int. Conf. on Image Processing*, ICIP'2005.

## *3.3 THESES*

In this section the Doctoral and Master theses concluded, or in progress, during 2004 at ISR-Lisbon are identified.

## 3.3.1 THESES CONCLUDED DURING 2004

## *DOCTORAL THESES (3)*

**Alexandre Bernardino, " Binocular Head Control with Foveal Vision: Methods and Applications", Ph.D. Thesis, Instituto Superior Técnico, April 2004, Lisboa, Portugal.**

**Abstract:**

The work in this thesis aims at the visual control of binocular robot heads with foveal images. Due to the complexity of visual processing in general settings, many biological systems have retinas with a small unique high resolution area called "fovea". To be able to perceive the whole environment, the observer uses attentional mechanisms to detect points of interest in the periphery of the visual field, and repositions the fovea to those points using eye movements. This strategy requires adequate oculomotor control mechanisms and efficient perceptual capabilities. The work in this thesis explores foveal vision, eye mobility, attentional mechanisms and efficient perceptual processing to develop a set of basic capabilities for the operation of a binocular head in realistic scenarios. We provide important contributions in the aspects of oculomotor control, foveal sensor design,
depth perception, motion estimation and selective visual attention. In the overall, we demonstrate the applicability and efficiency of foveal vision in all involved perceptual aspects.
Both computational and algorithmic advantages are illustrated along the thesis, and contribute toward the real-time operation of active artificial visual systems.

**Keywords:**

Foveal Vision, Binocular Heads, Visual Servoing, Depth Estimation, Motion Estimation, Visual Attention.

**Members of the thesis committee:**

**João José dos Santos Sentieiro,** Prof. Catedrático, IST, (P)
**Giulio Sandini, DIST,** Univ. Genova (I)
**João Manuel Lage de Miranda Lemos,** Prof. Catedrático, IST (P)
**Helder de Jesus Araújo, Prof. Associado,** Univ. Coimbra (P)
**Maria Isabel Lobato de Faria Ribeiro,** Prof. Associado, IST, (P)

**José Alberto Rosado dos Santos Victor,** Prof. Associado, IST, (P)

**Raquel Frizera Vassallo, "Uso de Mapeamentos Visuomotores com Imagens Omnidireccionais para Aprendizagem por Imitação em Robótica", Ph.D. Thesis, Universidade Federal do Espírito Santo, Setembro 2004, Vitória, Espírito Santo, Brasil.**

**Abstract:**

This work proposes an approach for robot task learning and adaptation. Learning relies on an action hierarchy where self-learning and imitation, based on sensorimotor representations, allows the robot to recognize its motor and sensorial capabilities and also to gradually define complex actions. A mobile robot application was implemented in order to test and illustrate the proposed ideas.

During a self-knowledge phase, the robot explores its own motor and sensorial capabilities. A sensorimotor mapping is defined relating robot's perception and movements. It converts sensorial information into motor data and allows recognizing and representing movements directly in motor space. Then, through imitation and using this sensorimotor mapping, the robot can learn a basic motor vocabulary. While observing and imitating other agents, the robot becomes able to learn, execute and recognize a set of elementary actions. Finally, these basic actions will be used to compose more complex actions, for each specific task domain. New actions are obtained by combining sequences of basic actions, learned a priori.

An application was implemented using a mobile robot with an omnidirectional and perspective cameras. A visuomotor mapping was derived relating robot's linear and angular velocities to omnidirectional optical flow. It was implemented as egomotion estimation performed analytically and either through neural networks. Imitation relied on following a colorful rectangle using the perspective camera. Through imitation, the robot learnt a basic motor vocabulary that was latter used to learn and perform more complex actions as topological mapping and navigation. Omnidirectional images were used to define nodes while motor words from the learnt vocabulary were used to define map links. The created map represents the environment in a motor way adapted to the robot capabilities. Until now we got encouraging results and believe that the approach might be extended to different robots and applications.

**Keywords:**

Vision based navigation, learning, visuomotor coordination.

**Members of the thesis committee:**

**Prof. Dr. Hans Jörg Andreas Schneebeli,** U. Federal Espírito Santo, (BR**)**
**Prof. Dr. José Santos-Victor,** IST, (P)
**Prof. Dr. Mário Sarcinelli Filho,** UFES, (BR)
**Prof. Dr. Evandro Ottoni Teatini Salles,** UFES, (BR**)**
**Prof. Dr. Mário Fernando Montenegro Campos,** U. Federal Minas Gerais (BR)
**Profa. Dra. Anna Helena Reali Costa,** U. São Paulo, (BR)

**Dejan Milutinovic, "Stochastic Model of Micro-Agent Populations", Instituto Superior Técnico, September 2004.**

**Abstract:**

This thesis describes an approach to the modeling and analysis of multi-agent populations composed by a large number of agents. The work is motivated by a systems theory approach to the modeling of a biological population of T-Cells. The dynamics of each individual cell is modeled by a deterministic Hybrid Automaton endowed with input events and continuous-valued outputs. The complex interaction among the population cells is modeled by stochastic events. This leads to a Stochastic Hybrid Automaton model, which results from inputting a stochastic event sequence to the individual cell model. The micro dynamics of each individual cell and the observed macro dynamics of the whole population are linked by

the application of a statistical physics reasoning to the complete model, through a system of partial differential equations describing the time evolution of a Stochastic Hybrid Automaton state probability density function. The T-Cell receptors triggering dynamics of the T-Cells population interacting with the population of antigen presenting cells is analyzed. The approach provides biologists with analytical tools to pose hypothesis about the individual T-Cell receptors dynamics and gain insight on how to interpret the biological experiments data. The T-Cell receptors distribution predictions based on biologically meaningful hypothesis are compared against the T-Cell receptors distribution data collected in biological experiments with the T-Cell population.
A similar approach can be applied to Robotics, more specifically to the modeling and control of large robotic populations. A scenario concerning the mission control of a robotic population is introduced and the corresponding Stochastic Hybrid Automaton model of the robotic population is presented. Under a stochastic control model, the robotic population can develop different shapes regarding the probability density function of the area occupied by the population robots. The optimal control problem of taking the population to a desired location with maximal probability within a given time instant is introduced. To solve this problem, the application of the Minimum Principle for the optimal control of partial differential equations is discussed.

**Keywords**: Biological Systems, Stochastic Hybrid Systems

**Members of the thesis committee:**

**Prof. João José dos Santos Sentieiro**, IST (P)
**Prof. Fernando Lobo Pereira**, FEUP (P)
**Prof. Michael Athans**, IST/MIT (P/USA)
**Dr. Jorge Carneiro,** IGC (P)
**Prof. Pedro Lima,** IST (P)

## *MASTER THESES (8)*

**Alpeshkumar Narotam Ranchordas, "Um Sistema de Realidade Aumentada sem Calibração", M.Sc. Thesis, Instituto Superior Técnico, June 2004, Lisboa, Portugal.**

**Abstract:**

Actualmente, com o advento da informática, as fotografias ou imagens vídeo ganharam um formato digital e o aumento da capacidade de cálculo contribuiu para agilizar a dinâmica das criações dos utilizadores. Com todo este desenvolvimento, a visão computacional viu-se beneficiada com surgimento de novas aplicações, como a Realidade Aumentada.

A Realidade Aumentada é uma área que consiste na integração de objectos gráficos em imagens reais previamente captadas de tal forma que não é fácil distinguir os objectos "adicionados" daqueles contidos na cena filmada. Um exemplo de aplicação que utilizam a realidade aumentada, é na habitação, que permite ao cliente fornecer uma cassete de vídeo da sua casa com vários pontos de vista, de um determinado local e, em tempo real, mostrar a nova plataforma anexada à sua casa. Na medicina onde informações provenientes de diversos sensores podem ser usadas para gerar imagens gráficas do interior do corpo humano ou ainda acrescentar gráficos ou outra informação às imagens visualizadas por um cirurgião. Da mesma forma, a realidade aumentada pode ser utilizada em outras áreas como: comércio do vestuário, entretenimento, na área da manutenção, arquitectura, educação, etc.

**Keywords:**

Câmaras afins, formação de imagem, calibração.

**Members of the thesis committee:**

**Prof. Dr. Helder de Jesus Araújo,** FCT, U. de Coimbra (P)

**Prof. Dr. José António da Cruz Pinto Gaspar,** IST (P)
**Prof. Dr. José Santos-Victor,** IST (P), Orientador Científico

**Paulo Lopes, "Bayesian Signal Reconstruction in Wireless Communication Systems with Spatial Diversity", Instituto Superior Técnico, April 2004, Portugal.**

**Abstract:**

In this thesis we study how the second-order statistics (SOS) of the observed data can be exploited in two signal processing problems: i) blind separation of instantaneously mixed binary sources, and ii) trained-based channel identification. In both aforementioned problems we work under a Bayesian framework. That is, a probability density function (pdf) is assumed for the unknown channel matrix. It is well known that, in a deterministic framework (channel matrix is unknown but deterministic), the SOS of the observed data permit to solve for the channel matrix up to a right unitary matrix. In our Bayesian framework, this residual unitary is now a random object. Its associated pdf depends solely on the prior pdf on the channel matrix and is easily computable. Our work capitalizes on this statistical knowledge to design improved signal processing techniques for the two aforementioned problems. More specifically, in problem i), we incorporate the pdf of the residual unitary matrix into the locally-convergent algorithm which implements the joint MAP channel/source estimator. Our computer simulations show that a better global convergence rate is obtained when compared to traditional schemes. In problem ii), exploitation of the residual pdf leads to more accurate channel estimators. In a scenario where the header od each transmitted data packet is known, the additional knowledge of the pdf of the residual unitary matrix probes to be advantageous in relation to traditional schemes in what refers to the estimation of the original channel matrix.

**Keywords:** Second-order statistics, Bayesian Frameworks, Blind Source Separation, Random Matrix Theory, Blind Channel Identification.

**Members of the thesis committee:**
**Prof. Paulo Jorge Ferreira,** Universidade de Aveiro (P)
**Prof. Mário Figueiredo,** IST (P)
**Prof. Victor Alberto Neves Barroso,** IST (P)
**Prof. João Manuel de Freitas Xavier,** IST (P)

**Maria da Graça Vieira de Brito Almeida, "Controlo de um Manipulador Robótico Usando Visão", M.Sc. Thesis, Instituto Superior Técnico, September 2004, Lisboa, Portugal.**

**Abstract:**

The vision system has been a natural allied of the robot arm. In fact, it is commonly accepted that one of the ways to increase the manipulator autonomy is to add visual capacity. The key issue relies on the relation of a bi-dimensional movement with the correspondent three-dimensional space movement. This correspondence is traditionally given by a procedure designated as calibration. This work makes use of a visual servo control (dynamic look-and-move). A Neural Network takes part on control chain imposing the relationship between the robot arm movements and the corresponding movements in the image. The network simulates the Jacobian of the robot arm and image avoiding the need to know the kinematics and vision system calibration. Experimental results are shown relating the use of a Mitsubishi robot arm with a vision system composed by a camera and a video frame grabber.

**Keywords:**

Robotic manipulation, robotic vision, visual servoing, capture based on vision, real time control, uncalibrated visual servoing.

**Members of the thesis committee:**
**Doutor João Rogério Caldas Pinto,** IST (P)

**Doutor José Alberto Rosado dos Santos Victor,** IST (P), co-orientador
**Doutor Paulo José Cerqueira Gomes da Costa,** Univ. Porto (P)
**Doutor Pedro Manuel Urbano de Almeida Lima,** IST (P), orientador

**Rui F. C. Guerreiro, "Modelos 3D densos a partir de imagens com sobreposição parcial: factorização com dados desconhecidos", Instituto Superior Técnico, September 2004, Portugal.**

**Abstract:**

This thesis addresses the problem of estimating 3D structure from motion with missing data. In this problem, I estimate the 3-D model of a static scene and the 3-D motion of the video camera from a video sequence with occlusion and inclusion. Occlusion and inclusion occur when parts of objects stop appearing or start appearing on the images, respectively. Although Tomasi and Kanade's factorization method is used extensively by the computer vision community to estimate structure from motion, it cannot handle occlusion and inclusion, which limits its practical use e causes a significative increase in computational complexity. In this thesis, I describe a new estimator of missing data in rank deficient matrices that estimates complete point trajectories from incomplete observed trajectories therefore eliminating the problem of occlusion and inclusion and reducing required computational complexity.
The estimation of missing data in rank deficient matrices consists of an algorithm that computes an initial estimate of the complete matrix and two iterative optimum algorithms that refine this estimate. One implements an Expectation-Maximization algorithm, and the other implements the Power Method algorithm
for missing data. These algorithms estimate the complete rank deficient matrix that best approximates the observation matrix with the same rank and missing data. These algorithms allow the use of Tomasi and Kanade's factorization method in real video sequences with a lot of occlusion and inclusion. In this study, I conclude that the missing data estimator in rank deficient matrices has important advantages regarding existing algorithms, in such aspects as estimation quality, computational cost and generality. This method eliminates the occlusion problem in a way that it estimates the optimum 3-D model with observed
data. In order to facilitate motion estimation in the video sequence, it is common to consider a first-order approximation in which we assume that the image motion can be approximated by a homographic transformation. In this thesis, I also describe a new homography and correspondence estimator, based on correlation optical flow, with a course-to-fine strategy.

**Keywords:**

Structure from motion, occlusion, inclusion, homography, correspondences, missing observations.

**Members of the thesis committee:**
**Prof. João Paulo Costeira,** IST (P)
**Prof. Helder de Jesus Araújo,** U. Coimbra (P)
**Prof. Pedro M. Q. Aguiar,** IST (P)

**Rui Carvalho, "Supply-Chains: an Multi-agent System Approach", Instituto Superior Técnico, September 2004, Lisboa, Portugal.**

**Abstract:**

The most important motivation for the realisation of this thesis was the possibility of study and integration of a set of knowledge from diversified scientific fields, such as Artificial Intelligence and Management Science/Economics. The main objective is the problem solving in Supply-Chain (SC) environments, through the implementation of a Multiagent System (MAS) constructed with that purpose.
The SC includes all the activities related with the production and transport of goods and the information flow associated with it. In the MAS are included an environment agent and other agents, clients and firms that negotiate relevant parameters through the use of tactics and strategies. Agents are computer systems capable of autonomous action, in some environment, in order to meet their design objectives. The communication is

possible with the support of a blackboard system, as the communication medium, an agent interaction protocol (Contract Nets), a reference for message format (e.g. KQML) and a specification for message content (e.g. KIF). For system evaluation, some systemic and problem specific indicators were calculated. The first, are related to the general behaviour of agents. In this thesis, problem specific indicators measure agent performance as firms within the SC. The literature review and results obtained, permitted the identification of the MAS capabilities, as a problem-solving tool, and of the main phenomena at SC systems.

**Keywords:**

Multi-Agent Systems, Supply Chains, Negotiation

**Members of the thesis committee:**
**Prof. Goran Putnik,** Universidade do Minho (P)
**Prof. Carlos Pinto-Ferreira,** IST (P)
**Prof. Luís Custódio,** IST (P)

**Pedro Alves, "Nonlinear Target Tracking" M.Sc Thesis, Instituto Superior Técnico, April 2004, Lisboa, Portugal.**

**Abstract:**
This thesis addresses the problem of tracking moving targets, in a two dimensional space. The main purpose of the work is to develop an obstacle avoidance system for an Autonomous Surface Craft, using the measurements obtained from vehicle sensors like Radars or Laser Range Finders. The thesis is organized as follows.

The first part of the thesis describes the sensors, their intrinsic limitations are analyzed and their finite resolution in both space and time are discussed. A statistical characterization of the sensors is presented and a probability density function of the target's position is derived using the measurements and the sensors intrinsic limitations presented before.
The second part of the thesis addresses the general problem of predicting the future position of one target. The complete nonlinear formulation of the problem is presented for the continuous and discrete time cases and practical approximations are derived to obtain algorithms that can be used in real world applications. Finally, the performance of the different algorithms is evaluated using simple dynamic models of oceanic vehicles.

The third part of this thesis addresses the problem of tracking a target using the data gathered from the sensors. The classical algorithms are presented for the linear and for the non-linear systems together with their limitations.
In the fourth part of the thesis, an alternative algorithm for non-linear tracking is derived using one of the non-linear predicting algorithms presented before. In this part, simulation results are presented and the limitations and performance are analyzed.

Each of the filters developed in the thesis presents good performance level in different situations. In the fifth part of this thesis an algorithm is derived for combining the estimates given by the different filters. The overall system proposed in this work is expected to use the estimate of the filter presenting better results in each situation.

**Keywords:**

Bayesian filtering, radar target tracking, multi-model target tracking, model switching, vehicle tracking.

**Members of the thesis committee:**
**Prof. João Miranda Lemos,** IST (P)
**Prof. José Azinheira,** IST (P)
**Prof. Sérgio Cunha,** FEUP (P)
**Prof. Carlos Silvestre,** IST (P)

**Christian Skaar, *"Coordination Motion Control,"* Department of Engineering Cybernetics / NTNU, Trondheim, Norway and Instituto Superior Técnico /ISR , Lisbon, Portugal, August 2004. Thesis research carried out at the ISR.**

**Abstract:**

The last two decades have witnessed the emergence of ocean robotics as a major field of research. Remotely operated vehicles (ROVs), and more recently autonomous underwater vehicles (AUVs), have shown to be extremely powerful instruments for the study and exploration of the ocean. Spawned by the availability of small embedded processors and the emergence of reliable acoustic communication systems, there is now increasing interest in the study of new methodologies for coordinated motion control of multiple marine vehicles. This trend is justified by a number of practical scenarios where ROVs, AUVs, and even autonomous surface vessels are required to cooperate towards the execution of tasks at sea.

Motivated by the above considerations, this thesis addresses the problem of coordinated motion control (CMC) of an ROV and an autonomous semi- submerged buoy (ASB). In the mission scenario proposed, the ROV is requested to follow a path by tracking a series of way-points in the horizontal plane. It is the task of the semi-submerged buoy to track the ROV and position itself along a vertical line directed to it. The key enabling element for the positioning of the buoy is an acoustic system that relies on the periodic emission of a signal emitted by a pinger installed on board the ROV. The times of arrival of the signal at a set of 4 hydrophones attached to the buoy can then be computed and fed into a kinematics-based navigation filter to yield robust estimates of the ROV's position in the presence of acoustic signal dropouts or outliers. Since the buoy is equipped with a GPS system, the problem of computing the exact position of the ROV underwater in real-time is thus naturally solved. The positioning data can then be relayed back to the ROV via the support ship and the umbilical.

The CMC referred to above consists therefore of three main sub-systems that are fully explored in the thesis. Namely, the ROV and its dynamic control system for way point tracking, an acoustic positioning system yielding the position of the underwater vehicle with respect to the buoy, and the ASB and its dynamic control system to track the ROV trajectory underwater.
The key goa of this thesisis to bring attention to the challenging problem of coordinated motion control and to carry out a study of the key concepts and methodologies that can be exploited to implement an acoustically based coordinated scheme for an ROV and a semi-submerged body. The thesis starts by introducing some basic background on ocean acoustics, as well as on the dynamics and kinematics of marine vehicles. Models for the ROV and the ASB are developed, together with thruster dynamics and thrusters allocation strategies. Environmental disturbances are taken into account when modelling the ASB motion (currents and surface waves) and the ROV motion (currents). A way point tracking algorithm for the ROV and a trajectory tracking controller for the ASB are developed by resorting to backstepping techniques. The acoustic positioning system that yields the relative position of the ROV with respect to the ASB is also discussed and modelled. All of the CMC sub-systems are implemented in Matlab/Simulink. Simulation results demonstrate the potential of the CMC strategy to effectively solve the problem of joint ROV / ASB operation.

**Keywords:**

Coordinated Motion Control, Marine Vehicles, ROVs, Backstepping Techniques

**Members of the thesis committee:**
**Prof. Thor Fossen,** NTNU, Trondheim, Norway
**Prof. António Pascoal,** IST (P)

**Havard Bo, "*Hydrodynamic Estimation and Identification,*" Department of Engineering Cybernetics / NTNU, Trondheim, Norway and Instituto Superior Técnico/ISR , Lisbon, Portugal, August 2004. Thesis research carried out at the ISR.**

**Abstract:**

This thesis addresses the problem of estimating the dynamics of an autonomous underwater vehicle (AUV). The theory presented is not limited to a specific design, but an autonomous underwater vehicle that is being developed under a joint Indian-Portuguese project, MAYA, will be used as an example. In order to obtain the dynamic equations of motion, we make use of empirical methods to obtain the hydrodynamic derivatives for a body of revolution. The USAF Stability and Control Datcom, a data compendium developed to determine the analogous aerodynamic stability derivatives for aircrafts, is used as a tool for obtaining estimates of the non-dimensional derivatives in an incompressible medium. The theory and equations involved are rewritten into a standard form for underwater vehicles.

A Matlab Toolbox, hde (short for HydroDynamic Estimation), is developed. The toolbox is capable of estimating static and dynamic derivatives in the horizontal and vertical plane, in addition to added mass in six degrees of freedom. A nonlinear simulation environment which retains all the nonlinearities inherent in the coupled dynamics equations of motion, as well as those inherent to the hydrodynamic relations which govern the forces acting on the hull and control planes, is also implemented as a part of the toolbox.

The results obtained from hde are compared with experimental data, where simulations in hde indicate that lift and turning rates are comparable with experimental data. The same yields for the added mass terms, which are very close to data reported from experimental results. Estimation of added mass for an AUV with the aid of WAMIT, a commercial hydrodynamic computation program, has been executed. The result from these experiments reveals that WAMIT fails to accurately estimate the added mass contribution from the low aspect-ratio foils involved in a typical AUV design.

**Members of the thesis committee:**
**Prof. Thor Fossen**, NTNU, Trondheim, Norway
**Prof. António Pascoal**, IST (P)
**Prof. Ettore Barros**, Univ. São Paulo (BR)

## 3.3.2 THESES IN PROGRESS DURING 2004

In this subsection the Doctoral and Master theses in progress during 2004, at ISR/IST (ECE) and ISR/Algarve (ECE), are identified and ordered by the scientific research area.

### *DOCTORAL THESES (35)*

**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 2004:** [135], [136]

**Research Area:** Formation Control with Obstacle and Collision Avoidance
**Title:**
**Doctoral Student:** Andrés García
**Advisor:** Pedro Lima
**Initiated:** March 2002
**Expected conclusion:** 2006
**Current Status:** On-going, passed Candidacy Exam, 1 PhD course left
**Documents produced in 2004:**

**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, 1 PhD course left
**Documents produced in 2004:** [12]

**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:** [12]

**Research Area:** Artificial Intelligence
**Title:** Emotion-based Agents
**Doctoral Student:** Rodrigo Ventura
**Advisor:** Carlos Pinto-Ferreira
**Initiated:** 2001
**Expected conclusion:** 2005
**Current Status:** On-going
**Documents produced in 2004:** [64]
**Research Area:** Computer Vision

**Title:** Vision based imitation
**Doctoral Student:** Manuel Cabido Lopes
**Advisor:** José Santos-Victor
**Initiated:** 2002
**Expected conclusion:** 2005
**Current Status:** On-going
**Grant:**
**Documents produced in 2004:** [74], [164]

**Research Area:** Computer Vision
**Title:** Recognition using Biological inspired filters.
**Doctoral Student:** Plínio Moreno Lopez
**Advisor:** José Santos-Victor
**Initiated:** 2002
**Expected conclusion:** 2006
**Current Status:** On-going

**Grant:** FCT
**Documents produced in 2004:** [73]

**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:** CAVIAR Project
**Documents produced in 2004:**

**Research Area:** Computer Vision
**Title:** Image matching
**Doctoral Student:** Ricardo Oliveira
**Advisor:** João Paulo Costeira
**Initiated:** 2001
**Expected conclusion:** 2004
**Current Status:** On-going
**Grant:** FCT
**Documents produced in 2004:**

**Research Area:** NeuroSciences
**Title:** Physilogical Modeling and characterization of olfactive discrimination in rats
**Doctoral Student:** Ernesto Soares
**Advisor:** Agostinho Cláudio da Rosa
**Initiated:** July 1999
**Expected Conclusion:** 2004
**Current Status:** Thesis Writing
**Grant:** Calouste Gulbenkian Foundation
**Documents produced in 2004:**

**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:** 1996
**Expected conclusion:** 2005
**Current Status:** on-going
**Grant:** Prodep
**Documents produced in 2004:** [39]

**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:** 2005
**Current Status:** on-going
**Grant:** FCT
**Documents produced in 2004:**

**Research Area:** Biomedical Engineering - Neuroscience
**Title:** Biological Intelligent Machine Learning
**Doctoral Student:** Jose Luis Malaquias
**Advisor:** Agostinho Cláudio da Rosa
**Initiated:** September 2000
**Expected Conclusion:** 2004
**Current Status:** Delivered for discussion
**Grant:**
**Documents produced in 2004:**

**Research Area:** Biomedical Engineering
**Title:** A Bio-computational model of the human vision
**Doctoral Student:** Raquel César
**Advisor:** Agostinho Rosa
**Initiated:** 2004
**Expected Conclusion:** 2007
**Current Status:** initiated
**Grant:** FCT
**Documents produced in 2004:**

**Research Area:** Evolutionary Algorithms
**Title:** Antropologic Evolutionary Algorithms
**Doctoral Student:** Carlos Fernandes
**Advisor:** Agostinho Rosa
**Initiated:** October 2004
**Expected Conclusion:** 2008
**Current Status:** initiated
**Grant:** FCT
**Documents produced in 2004:**

**Research Area:** Biomedical Engineering
**Title:** Eletronmicroscope Image Processing - Dual Cell Classification
**Doctoral Student:** Julhilson Junior
**Advisor:** Agostinho Rosa
**Initiated:** October 2004
**Expected Conclusion:** 2008
**Current Status:** initiated
**Grant:** FCT
**Documents produced in 2004:**

**Research Area:** Evolutionary Algorithms
**Title:** Parallel Evolutionary Algorithms
**Doctoral Student:** João Paulo Caldeira
**Advisor:** Agostinho Rosa
**Initiated:** October 2004
**Expected Conclusion:** 2008
**Current Status:** initiated
**Grant:**
**Documents produced in 2004:** [98], [100]

**Research Area:** Evolutionary Algorithms
**Title:** Linguistic modelling by Evolutionary Algorithms
**Doctoral Student:** Rui Tavares
**Advisor:** Agostinho Rosa
**Initiated:** October 2004
**Expected Conclusion:** 2008
**Current Status:** initiated
**Grant:**
**Documents produced in 2004:**

**Research Area:** Statistic based navigation of mobile robots in outdoors environments
**Title:** Mobile Robot Navigation in Outdoor Environments: A Topological Approach
**Doctoral Student:** Alberto Manuel Martinho Vale
**Advisor:** Maria Isabel Ribeiro
**Initiated:** 2000
**Expected conclusion:** June 2005
**Current Status:** on-going
**Grant:** SFRH/BD/929/2000 from FCT
**Documents produced in 2004:** [79], [140]

**Research Area:** Control of a Mobile Robot Population
**Title:** Learning Cooperative Navigation in the Absence of Communication
**Doctoral Student:** Francisco António Saraiva Melo
**Advisor:** Maria Isabel Ribeiro
**Initiated:** December 2002
**Expected conclusion:** 2006
**Current Status:** on-going
**Grant:** PhD grant from FCT
**Documents produced in 2004:** [59], [81], [137], [140]

**Research Area:** Space/Time Coding
**Title:** Noncoherent Communication in Multi-antenna Wireless Systems
**Doctoral Student:** Marko Beko
**Advisor:** João Xavier
**Initiated:** 2003
**Expected conclusion:** 2006
**Current Status:** on-going
**Grant:** PhD FCT grant
**Documents produced in 2004:**

**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 2005
**Current status:** on going
**Grant:** FCT doctoral fellowship
**Documents produced in 2004:** [101], [102], [105], [106], [115]

**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 2004:** [105], [144], [158]

**Research Area:** Underwater Acoustic Communications
**Title:** Environmentally robust methods for underwater acoustic communications
**Doctoral Student:** Antonio João Silva
**Advisor:** Sérgio M. Jesus
**Initiated:** July 2003
**Expected conclusion:** 2006
**Current status:** on going
**Grant:** Teaching Assistant (PRODEP fellowship)
**Documents produced in 2004:** [101], [103], [106]

**Research Area**: Evolutionary Systems - Scheduling
**Title:** Automatização de horários escolares
**Doctoral Student:** Fernando Melício
**Advisor:** Agostinho Cláudio da Rosa
**Initiated:** 1998
**Expected Conclusion:** 2005
**Current Status:** Delivered for defense
**Grant:**
**Documents produced in 2004:** [98], [100]

**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:** 2001
**Expected Conclusion:** 2005
**Current Status:** Delivered for defense
**Grant:** FCT
**Documents produced in 2004:** [29], [30]

**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:** 2005
**Current Status:** Delivered for defense
**Grant:** FCT
**Documents produced in 2004:**

**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 2004:** [128]

**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 2004:** [55] , [137]

**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 2004:** [50], [124], [125], [151]

**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 2004:** [132]

**Research Area:** Control Theory
**Title:** Robust Adaptive MIMO Control using Multiple-Model Hypothesis Testing and Mixed μ-Synthesis
**Doctoral Student:** Sajjad Fekri Asl
**Advisor:** Michael Athans / António Pascoal
**Initiated:** 2002
**Expected Conclusion:** 2005
**Current Status:** On-going
**Grant:** FCT Graduate Scholarship
**Documents produced in 2004:** [47], [48], [49], [123]

**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 2004:** [45] , [117]

**Research Area:** Control Theory
**Title:** Modeling and Coordinated Path Following Control of Fully Actuated Marine Vehicles
**Doctoral Student:** Danilo Carvalho
**Advisor:** Teodiano Filho (Univ. Federal Espírito Santo, Brasil) / António Pascoal
**Initiated: 2002**
**Expected Conclusion:** 2006
**Current Status:** On-going
**Grant:** "Sandwich Doctoral Program" financed by the Brasilian Government.
**Documents produced in 2004:** [121]

**Research Area**: Tomographic Data Assimilation/Signal Processing
**Title:** Data Fusion Applied to Ocean Acoustic Tomography
**Doctoral Student:** Paulo S. Felisberto
**Advisor:** Sergio M. Jesus
**Initiated:** June 2000
**Expected Conclusion**: 2004
**Current status:** Delivered for defense
**Grant:** Teaching Assistant (PRODEP fellowship)
**Documents produced in 2004**: [40], [114]

## *MASTER THESES (20)*

**Research Area:** Multi-Robot Sensor Fusion and World Modeling
**Title:**
**Master Student:** Pedro Pinheiro
**Advisor:** Pedro Lima
**Initiated:** 2003
**Expected conclusion:** 2005
**Current Status:** writing thesis
**Documents produced in 2004:** [56]

**Research Area:** Artificial Intelligence
**Title:** Emotion-based Agent Architectures
**Master Student:** Bruno Damas
**Advisor:** Luis Custódio
**Initiated:** 2002
**Expected conclusion:** 2005
**Current Status:** On-going
**Documents produced in 2004:**

**Research Area:** Artificial Intelligence
**Title:** Agents with Personality: Application to the Robotic Soccer case-study
**Master Student:** Carla Penedo
**Advisor:** Luis Custódio
**Initiated:** 2002
**Expected conclusion:** 2005
**Current Status:** On-going
**Documents produced in 2004:**

**Research Area:** Artificial Intelligence
**Title:** Development of Coach Agent for a Robotic Soccer Team
**Master Student:** João Pavão
**Advisor:** Luis Custódio
**Initiated:** 2002
**Expected conclusion:** 2005
**Current Status:** On-going
**Documents produced in 2004:**

**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:** 2005
**Current Status:** On-going
**Documents produced in 2004:** [61], [112]

**Research Area:** Artificial Intelligence
**Title:** Learning and Logical Decision-Making for a Multi-robot Team
**Master Student:** Vasco Pires
**Advisor:** Luis Custódio
**Initiated:** 2003
**Expected conclusion:** 2005
**Current Status:** Waiting discussion
**Documents produced in 2004:** [61], [112]

**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 2004:**

**Research Area:** Computer Vision
**Title:** Tracking of articulated Objects
**Master Student:** Ricardo Marranita
**Advisor:** José Santos-Victor
**Initiated:** 2002
**Expected conclusion:** 2005
**Current Status:** on-going
**Grant:**

**Documents produced in 2004:**

**Research Area:** Biomedical Engineering
**Title:** Processamento de imagens em microscopio confocal
**Master Student:** Alexandre Calapez
**Advisor:** Agostinho Rosa
**Initiated:** 2002
**Expected Conclusion:** 2005
**Current Status:** Thesis writing
**Grant:**
**Documents produced in 2004:**

**Research Area:** Evolutionary System
**Title:** Intelligent Evoltionary Learning
**Master Student:** Ivo Bhatt
**Advisor:** Agostinho Rosa
**Initiated:** 2004
**Expected Conclusion:** 2006
**Current Status:** Initiated
**Grant:**
**Documents produced in 2004:**

**Research Area:** Applied robotics
**Title:** Inspecção e Manutenção Robótica em Linhas de Transporte de Energia Eléctrica de Alta Tensão
**Master Student:** José Inácio Rocha
**Advisor:** João Sequeira
**Initiated:** 2001
**Expected conclusion:** 2005
**Current Status:** Submitted
**Grant:**
**Documents produced in 2004:** [82], [83]

**Research Area:** Applied robotics
**Title:** Groove Opening Robot for the Civil Construction Industry
**Master Student:** Carlos Alfaro
**Advisor:** João Sequeira
**Initiated:** 2002
**Expected conclusion:** 2005
**Current Status:** on-going
**Grant:**
**Documents produced in 2004:** [113]

**Research Area:** Applied robotics
**Title:** Cooperative Localization of a multi-robot system
**Master Student:** João Casaleiro
**Advisor:** M. Isabel Ribeiro
**Initiated:** 2004
**Expected conclusion:** 2005
**Current Status:** On-going
**Grant:**
**Documents produced in 2004:**

**Research Area:** Evolutionary Systems - BioChemistry
**Title:** Algoritmo para Evolução de Redes Neuronais no alinhamento Múltiplo de Sequências Proteicas
**Master Student:** Nelson Pereira
**Advisor:** Agostinho Rosa
**Initiated:** 2001
**Expected Conclusion:** 2005
**Current Status:** delivered for defense
**Grant:** FCT
**Documents produced in 2004:**

**Research Area:** Real Time Systems
**Title:** Real Time Architectures for Autonomous Vehicles
**Master Student:** João Alves
**Advisor:** Carlos Silvestre
**Initiated:** 2002
**Expected Conclusion:** 2005
**Current Status:** On-going
**Grant:** IST/ AdI-MAYA project
**Documents produced in 2004:** [118]

**Research Area:** Control of Autonomous Vehicles
**Title:** Terrain Tracking Strategies for Autonomous Vehicles with application to Unmanned Helicopters
**Master Student:** Nuno Paulino
**Advisor:** Carlos Silvestre
**Initiated:** 2003
**Expected conclusion:** 2005
**Current Status:** On-going
**Grant:** FCT/Alticopter Project
**Documents produced in 2004:** [128]

**Research Area:** Navigation and Positioning Systems
**Title:** Underwater Positioning Methodologies: Limits of performance and Implementation Issues
**Master Student:** Carla Viveiros
**Advisor:** Paulo Oliveira
**Initiated:** 2004
**Expected conclusion:** 2007
**Current Status:** On-going
**Grant:**
**Documents produced in 2004:**

**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:** 2005
**Current Status:** On-going
**Grant:** IST/ AdI-MEDIRES project
**Documents produced in 2004:** [120]

**Research Area:** Artificial Intelligence
**Title:** Learning on a Multi-Agent Soccer Robotic System
**Master Student:** Pedro Nunes
**Advisor:** Luís Manuel Marques Custódio

**Initiated:** 2002
**Expected conclusion:** 2004
**Current Status:** on-going
**Grant:**
**Documents produced in 2004:**

**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 2004:**

## *3.4 ADVANCED TRAINING*

### *3.4.1 COURSES*

**José Santos-Victor –** "Statistical and Computational Models of Vision", Ph.D. Course, IST.

**Luis Custódio –** "Artificial Intelligence", M.Sc. Course, Post-Graduation on Electrical and Computers Engineering at IST.

**Pedro Lima and M. Isabel Ribeiro –** Mobile Robotics M.Sc. Course, Instituto Superior Técnico, Lisbon, Portugal.

**Michael Athans and Carlos Silvestre – "**Design of Robust Multivariable Feedback Control Systems", a one semester doctoral level course taught at IST.

**Michael Athans and Paulo Oliveira – "**Dynamic Stochastic Estimation, Prediction and Smoothing", a one semester doctoral level course taught at IST.

**António Pascoal,**"*Modeling and Control of Marine Craft*," an intensive 15 hours Post-Graduate Course taught at the Department of Electrical Engineering, Universidade Federal do Espírito Santo (UFES), Vitoria, Espírito Santo, Brasil.

### *3.4.2 SEMINARS*

- **During 2004 the following Seminars were given outside ISR:**

**Luis Custódio** - "Sistemas Inteligentes Multi-Robot: investigação desenvolvida no ISR/IST", ITA - Instituto Tecnológico de Aeronáutica, São José dos Campos, Brasil, March 2004.

**Pedro Lima –** "Models of Robotic Tasks Based on Discret Event and Hybrid Systems", Logic and Computation Seminar, IST Math Department, March 2004.

**Luis Custódio** - "Sistemas Inteligentes Multi-Robot: investigação desenvolvida no ISR/IST", Faculdade de Ciências da Universidade de Lisboa, June 2004.

- **Some ISR Laboratories, such as Vislab, DSOR lab and ESBE lab organize internal weekly meetings.**

- **ISR Regular Seminars:**

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

**Andrés García** - "The Concept of Controlled Eigenvectors for Affine Non-Linear Systems Applied to Vehicle Formations Control", Mathematics, Systems and Robotics Seminar, IST Math Department and ISR/IST, March 2004.

**Dejan Milutinovic – "**Modeling and Control of a Large-Size Robotic Population", Instituto de Sistemas e Robótica do IST, ISR internal seminar, March 2004.

**Dejan Milutinovic** - "Stochastic Model of Micro-Agent Populations", ISR Seminar 17 March, and Center for Mathematical Analysis, Geometry and Dynamical Systems, March 2004.

**Reza Ghabcheloo –** "Coordinated Path Following Control of Multiple Wheeled Robots", Instituto de Sistemas e Robótica do IST, ISR internal seminar, March 2004.

**AlbertoVale –** "Topological Navigation in Outdoor Environments", Instituto de Sistemas e Robótica do IST, ISR internal seminar, June 2004.

**Alex Alcocer –** "Study and Implementation of an EKF GIB-Based Underwater Positioning System", Instituto de Sistemas e Robótica do IST, ISR internal seminar, November 2004.

**Margarida Silveira** - "Segmentation of Multiple Objects", IST, November 2004.

**Artur Arsénio -** Artificial Brains for Artificial Beings – on Developmental Perception and Learning for the Humanoid Robot COG, December 2004.

### *3.4.3 VISITS ABROAD*

**António Pascoal -** Associate Visiting Professor, January–February 2004 – Department of Electrical Engineering, Federal Univ. Espirito Santo, Vitória, Brasil.

**António Pascoa**l – Department of Mechatronics, Univ. São Paulo (USP), São Paulo, Brasil, February 2004.

**Carlos Silvestre -** Royal Military College of Science, Cranfield University, Shrivenham Swindon United Kingdom, March 2004.

**Luís Custódio –** ITA – Instituto Tecnológico de Aeronáutica, São José dos Campos, Brasil, March 2004.

**Luís Custódio** - Escola Politécnica, Universidade de São Paulo (USP), São Paulo, Brasil, March 2004.

**José-Santos Victor -** INRIA-Rhone Alpes, June 2004.

**Alexandre Bernardino** INRIA-Rhone Alpes, June 2004.

**José-Santos Victor –** Institute of Action and Perception, Unversity of Edimburgh, September 2004.

**Alexandre Bernardino –** Institute of Action and Perception, Unversity of Edimburgh, September 2004.

**José-Santos Victor -** INRIA Projects Lagadic and Vista, Rennes, France, December 2004.

**Alexandre Bernardino** INRIA Projects Lagadic and Vista, Rennes, France, December 2004.

**Agostinho Claúdio da Rosa** - Visiting Professor at School of Medicine, Federal University of Sao Paulo, Brazil.

**M. Isabel Ribeiro –** UPC, Barcelona, February and October 2004.

### *3.4.4 SUPERVISION OF STUDENTS ENROLLED IN FOREIGN UNIVERSITIES*

**Pedro Lima** - Supervisor of Valguima Odakura, Ph.D. Student from Universidade Politécnica de São Paulo, Brasil – six month period at ISR/IST, September 2003 to March de 2004.

**Pedro Lima –** Supervisor of Bob van der Vecht, Artificial Intelligence/U. Gröningen, Gröningen - TFC realized at ISR/IST, "Behaviour Coordination for Cooperative Multi-Robot Systems", September 2003 to March 2004.

**José Santos-Victor –** Co-supervisor of Raquel Vassallo, Ph.D. student, University of Espírito Santo, Vitória, Brasil.

**José Santos-Victor** - Co-supervisor of Roger Freitas, Ph.D. student, University of Espírito Santo, Vitória, Brasil.

**José Santos-Victor** - Co-supervisor of Filiberto Pla, Post Doc, University Jaume I, Castellon, Spain.

**José Santos-Victor –** Co-supervision of Luís Montesano, visiting Ph.D. student, University of Zaragoza, Spain.

**José Gaspar -** Co-supervision of Luís Montesano, visiting Ph.D. student, University of Zaragoza, Spain.

**Alexandre Bernardino –** Co-supervisor of Julio Perez, visiting student, University Jaume I, Castellon, Spain.

**Agostinho Rosa –** Co-supervisor of Roberta Vilhena Vieira, DCC-Universidade Federal de Pernambuco, Brasil

**António Pascoal –** Co-supervision by Prof. Teodiano Filho (Univ. Federal Espírito Santo - UFES, Vitória, Espírito Santo, Brasil) of the PhD research program of Danilo Carvalho, a PhD student enrolled at UFES, doing a "Sandwich Doctoral Program" financed by the Brasilian Government. The main topic of his PhD thesis is "Modeling and Coordinated Path Following Control of Fully Actuated Marine Vehicles".

**António Pascoal** - Co-supervision by Prof. Thor Fossen (NTNU, Trondheim, Norway) of the M.Sc. researchprogram of Christian Skaar , a PhD student enrolled at the Department of Engineering Cybernetics/ NTNU, Trondheim, Norway. The title of his thesis is "Coordination Motion Control".

**António Pascoal** - Co-supervision by Prof. Thor Fossen (NTNU, Trondheim, Norway) , and Prof. Ettore Barros, Univ. São Paulo, Brasil - of the M.Sc. research program of Havard Bo , a PhD student enrolled at the Department of Engineering Cybernetics / NTNU, Trondheim, Norway. The title of his thesis is "Hydrodynamic Estimation and Identification".

## *3.5 CONGRESS, MEETINGS AND PRESENTATIONS*

This section includes invited talks, conferences attended and conferences where papers were presented, during 2004, by ISR-Lisbon researchers.

### *3.5.1 INVITED TALKS*

**António Pascoal –** "Marine Robotics: Research and Development", Invited Talk, Department of Mechatronics, Universidade de São Paulo (USP), São Paulo, Brasil, February 2004.

**António Pascoal –** "Marine Robots as Advanced Tools for Oceanography", Invited Talk, Department of Oceanography, Universidade Federal do Espírito Santo (UFES), Vitoria, Espírito Santo, Brasil, February 2004.

**Paulo Oliveira –** "Veículos Robóticos Autónomos Oceânicos: ferramentas para conhecer melhor o mundo que nos rodeia", Invited Talk, Workshop for Science, Education and Marine Archeology Program in Portugal, Centro Ciência Viva do Algarve, February 2004.

**Carlos Silvestre -** "Research Activities at the Dynamic Systems and Ocean Robotics Lab. of ISR-Lisbon", Invited Talk, Royal Military College of Science, Cranfield University, Shrivenham Swindon, United Kingdom, March 2004.

**Luís Custódio –** "Sistemas Inteligentes Multi-Robot: investigação desenvolvida no ISR/IST", Workshop of the Laboratório de Técnicas Inteligentes (LTI), Escola Politécnica, Universidade de São Paulo (USP), São Paulo, Brasil, March 2004.

**Alberto Vale –** "Navegação Topológica do Atrv Jr – Veículo todo-o-terreno do projecto RESCUE", Semana Informática, IST, Lisbon, March de 2004.

**Pedro Lima –** "Competições de Robots em Portugal", Semana Informática 2004, March 2004.

**Pedro Lima –** "I&D em Robótica de Serviços – Projectos SocRob, Rescue e RAPOSA", Semana Informática 2004, IST, Lisbon, March 2004.

**Pedro Lima –** "Navegação de Robots Móveis em Ambientes Dinâmicos", II Jornadas de Engenharia Electrotécnica – Tecnologia em Movimento, Escola Superior de Tecnologia de Tomar, April 2004.

**Carlos Silvestre -** "Marine Robots as Advanced Tools for Archaeology", Invited Talk, SCAM Workshop on Inovative Technologies for Underwater Archaeology, La Spezia, Italy, April 2004.

**M. Isabel Ribeiro –** "Os homens e os robots na casa do futuro", 3ª Semana de Arquitectura, IST, Lisbon, May 2004.

**José Santos-Victor –** "3D Vision," V Jornadas Ibero-Americanas de Robótica, Santa Cruz de La Sierra, Bolívia, May 2004.

**Agostinho Rosa –** "Computação Evolutiva e Aplicações em Biomedicina", Dep Eng Elect, POLI-USP, Sao Paulo, Brasil, May 2004.

**Alberto Vale –** "Inteligência Artificial e Robótica " – Escola Secundária com 3º CEB de Gouveia, Gouveia, Portugal, June 2004.

**Sérgio M. Jesus** - "Towards an Easily Deployable, Reconfigurable Multifunctional Acoustic - Oceanographic System", Naval Research Laboratory, Washington DC, USA, July, 2004.

**Pedro Lima –** "A Robótica como Ciência Multidisciplinar", Fórum Internacional dos Investigadores Portugueses, Coimbra, July 2004.

**M. Isabel Ribeiro –** "Navegação e controlo de robots autónomos e semi-autónomos em ambientes não estruturados", Fórum Internacional dos Investigadores Portugueses, Coimbra, Portugal, July 2004.

**Agostinho Rosa –** "Modelos de Eventos no Sono" – Universidade Federal Rio Grande do Sul, Porto Alegre, Brasil, July 2004.

**Agostinho Rosa –** CAP – Associação Paulista de Medicina – APM, São Paulo, Brasil, August 2004.

**Agostinho Rosa –** "Algoritmos Evolutivos"– Instituto Tecnológico da Aeronautica - ITA, S. José dos Campos, SP, Brasil, August 2004.

**M. Isabel Ribeiro –** "Uma Viagem ao Mundo dos Robots", invited talk in the cycle Despertar para a Ciência 2004, organized by Calouste Gulbenkian Foundation (FCG) and Portuguese Foundation for Science and Technology (FCT), Lisbon, September 2004.

**M. Isabel Ribeiro –** "Uma Viagem ao Mundo dos Robots", invited talk in the cycle Despertar para a Ciência Açores 2004, organized by Calouste Gulbenkian Foundation (FCG), Portuguese Foundation for Science and Technology (FCT) and University of Açores, Ponta Delgada, Açores, November 2004.

**Agostinho Rosa –** "Padrão Alternante Cíclico – Uma nova forma de classificação do sono" – Congresso da Associação Argentina da Medicina do Sono. Buenos-Aires, Argentina, December 2004.

**João Xavier –** "New Statistical Bound for Inference Problems on Riemannian Manifolds", IEEE Workshop on Signal Processing Advances on Wireless Communications (SPAWC'2004), Lisbon, Portugal, 2004.

### *3.5.2 PARTICIPATIONS*

**During 2004, ISR-Lisbon researchers participated in the following International Conferences, Workshops and Meetings:**

8th Conference on Intelligent Autonomous Systems – IAS8, Amsterdam, Netherlands, March 2004.

EURON annual meeting, Amsterdam, Netherlands, March 2004.

35th International Symposium on Robotics, Paris-Nord Villepinte, France, March 2004.

4th Portuguese Robotics Festival, Porto, April 2004.

IEEE International Conference on Acoustics, Speech and Signal Processing ICASSP 2004, Montreal, Canada, May 2004.

2nd Summer School on Simultaneous Localization And Mapping, Toulouse, France, August 2004.

4th International Workshop on Robot Motion and Control, RoMoCo'04, Puszczykowo, Poland, June 2004.

V IEEE International Workshop on Signal Processing Advances in Wireless Communications, Lisbon, Portugal, June 2004.

12th IEEE Mediterranean Conference on Control and Automation (MED 2004), Turkey, June, 2004.

IFAC Conference on Control Applications in Marine Systems (CAMS 2004), Ancona, Italy, July, 2004.

5th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC'04), Lisbon, Portugal, July 2004.

5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles, Lisbon, Portugal, July 2004.

RoboCup Symposium, Lisbon, July 2004.

ICCE2004 29th International Conference on Coastal Engineering, Lisbon, Portugal, September 2004.

IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS2004, Sendai, Japan, September 2004.

IEEE Multimedia Signal Processing Workshoip, Siena, Italy, September 2004.

EURON Education Key Area, Barcelona, Spain, February and October, 2004.

IEEE Int. Conf. Image Processing, Singapore, October 2004.

Congress of Latin-America Sleep Medicine, Montevideo, Uruguai, November 2004.

## *3.6 SERVICE ACTIVITIES*

This section is dedicated to service activities developed, during 2004, by ISR-Lisbon researchers as members of the national and international scientific community.

### *3.6.1 EDITORIAL BOARDS*

**Agostinho Rosa –** Associate Editor of the International Journal of Information & Communication Technology in Education.

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

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

**Sérgio M. Jesus** - Co-editor of the book "Acoustic Inversion Methods and Experiments for Assessment of the Shallow Water Environment" to appear on KLUWER, 2005.

**Victor Barroso –** Associate Editor of the IEEE Signal Processing Letters.

### *3.6.2 ADVISORY BOARDS*

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

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

**António Pascoal -** Member, 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.

**António Pascoal** - Member, 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.

**Isabel Lourtie** - Associated member of the IEEE Sensor Array and Multichannel Technical Committee.

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

**M. Isabel Ribeiro –** Vice-chair of the IFAC Technical Committee on Intelligent Autonomous Vehicles.

**Pedro Lima –** Trustee of the RoboCup Federation.

**Victor Barroso –** Chair of the steering committee of the IEEE Transactions on Mobile Computing.

**Victor Barroso** - Member of the IEEE Sensor Array and Multichannel Technical Committee.

### *3.6.3 PROGRAMME AND TECHNICAL COMMITTEES*

**Agostinho Rosa** – Member of the Programme Committee of the IRMA 2004 – International Conference of Information Resources Management Association, New Orleans, USA, May 23-26, 2004.

**Agostinho Rosa** – Member of the Programme Committee of the ICEIS 04 – Artificial Intelligence - Porto, Portugal, 2004.

**Agostinho Rosa** – Member of the Programme Committee of the ACM SAC' 04 – Evolutionary Computation and Optimization, Nicosia, Cyprus, 2004.

**Agostinho Rosa** – Member of the Programme Committee of the BIOMED 2004 - IASTED – International Conference on Biomedical Engineering, Insbruck, Austria, September 2004.

**Agostinho Rosa** – Member of the Programme Committee of the ICINCO 2004 – Informatics in Control, Automation and Robotics, Setúbal, Portugal.

**Agostinho Rosa** – Member of the Programme Committee of the IAV 2004 – IFAC/EURON Symposium on Intelligent Autonomous Vehicles, Lisbon, Portugal, 2004.

**Alexandre Bernardino -** Member of the Programme Committee and Local Arrangements Chair, IFAC/Euron Symposium on Intelligent Autonomous Vehicles, IAV2004, Lisbon, June 2004.

**António Pascoal** - Program Vice-Chair, 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles, IAV 2004, Lisbon, Portugal, July, 2004.

**António Pascoal** - Member, International Program Committee, IEEE Conference on Intelligent Robots and Systems, IROS´04, Japan.

**António Pascoal** - Member, International Program Committee, IFAC Conference on Control Application in Marine Systems (CAMS 2004), Ancona, Italy, July 2004.

**António Pascoal** - Member, International Program Committee, MED'04, Turkey.

**João Gomes** - Treasurer and Member of the Technical Committee of the 2004 IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC'2004).

**João Paulo Costeira -** Member of the Programme Committee and Local Arrangements Chair, 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles, IAV2004, Lisbon, July 2004.

**João Xavier** - Member of the technical committee of the 2004 IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC'2004), July 2004.

**Jorge S. Marques** - Member of the Local Committee and Program Committee of the Syntatical and Structural Pattern Recognition (SSPR), Lisbon, August 2004.

**Jorge S. Marques** - Member of the Program Committee of the International Conference on Image Analysis and Recognition (ICIAR), Porto, September 2004.

**Jorge S. Marques** - Member of the Program Committee of 9th Iberoamerican Congress on Pattern Recognition (CIARP) , Puebla, Mexico, October 2004.

**Jorge S. Marques** - Member of the Program Committee of the 2nd Ibero-American Symposium on Computer Graphics and Image Processing (SIBGRAPI), Curitiba, Brasil, October 2004.

**José Santos-Victor -** Area-Chair, European Conference on Computer Vision, ECCV, Prague, Czech Republic, May 2004.

**José Santos-Victor -** Co-Chair and Member of the Programme Committee of the 6th IEEE International Workshop on Performance Evaluation of Tracking and Surveillance, PETS2004, Prague, Czech Republic, May 2004.

**José Santos-Victor -** Member of the Programme Committee of the 5th Workshop on Omnidirectional Vision, Camera Networks and Non-classical cameras, Omnivis2004, Prague, Czech Republic, May 2004.

**José Santos-Victor -** Member of the Programme Committee and Co-Editor, 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles, IAV2004, Lisbon, July 2004.

**José Santos-Victor -** Member of the Programme Committee and Co-chair, RoboCup Symposium, ROBOCUP2004, Lisbon, June 2004.

**José Santos-Victor -** Member of the Programme Committee, British Machine Vision Conference RoboCup Symposium, BMVC 2004, London, United Kingdom, September 2004.

**José Santos-Victor -** Member of the Programme Committee, IEEE Computer Society Conference on Computer Vision and Pattern Recognition, CVPR, Washington, DC, 27th June - 2nd July, 2004

**Luís Custódio –** Member of the Program Committee of the 9th Iberoamerican Conference on Artificial Intelligence, IBERAMIA 2004, November 2004.

**Luís Custódio –** Member of the Program Committee of the International Conference on Informatics in Control, Automation and Robotics, ICINCO – 2004, Setubal, Portugal, August 2004.

**Luís Custódio –** Member of the Technical-Scientific Committee of the Portuguese Robotics Open (Festival Nacional de Robótica).

**Luís Custódio** - Third International Symposium "Affective Computational Entities", 17th European Meeting on Cybernetics and Systems Research (EMCSR'04), April 2004.

**Luís Custódio –** General Chair of RoboCup 2004, Lisboa, Portugal, June-July 2004.

**M. Isabel Ribeiro –** Member of the International Program Committee of the 2004 IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS2004, Sendai, Japan, September-October 2004.

**M. Isabel Ribeiro –** Member of the International Program Committee of the 1st International Conference on Informatics in Control, Automation and Robotics, ICINCO2004, Setúbal, Portugal, August 2004.

**M. Isabel Ribeiro –** General Chair, Chair of the International Program Committee and Co-Editor of the 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles, IAV2004, Lisbon, Portugal, July 2004.

**M. Isabel Ribeiro –** Member of the International Program Committee of the 7th International Symposium on Distributed Autonomous Robotic Systems, DARS2004, Toulouse, France, June 2004.

**M. Isabel Ribeiro –** Member of the International Program Committee of the 6th Portuguese Conference on Automatic Control, CONTROLO'2004, Faro, Portugal, June 2004.

**M. Isabel Ribeiro** - Member of the Program Committee of the Scientific Meeting of the 4th Robotics National Festival, Robótica2004, Porto, April 2004.

**M. Isabel Ribeiro –** Member of the International Program Committee of the 8th Conference on Intelligent Autonomous Systems – IAS8, Amsterdam, Netherlands, March 2004.

**Paulo Oliveira** - Member, Scientific Committee the 2004 National Robotics Meeting, Oporto, April 2004.

**Paulo Oliveira** - Local Arrangements Manager for the World Robocup 2004, June 2004, Lisbon.

**Pedro Lima –** Co-organizer (with Alessandro Saffiotti, Örebro University, Sweden) of the IEEE International Conference on Robotics and Automation, 2005 Workshop on Cooperative Robotics.

**Pedro Lima –** Member of the International Program Committee of the IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS2004, September de 2004, Sendai, Japan.

**Pedro Lima** - Member of the International Program Committee of the 8th Conference on Intelligent Autonomous Systems – IAS8, Amsterdam, Netherlands, March 2004.

**Pedro Lima** - Member of the International Program Committee of the 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles, Lisbon, Portugal, July 2004.

**Pedro Lima –** Member of the International Program Committee of the IASTED International Conference on Modelling, Identification and Control (MIC 2004), February 2004, Grindelwald, Switzerland.

**Pedro Lima –** Founding member of the Technical-Scientific Committee of the Portuguese Robotics Open (Festival Nacional de Robótica).

**Pedro Lima –** General chair of RoboCup 2004, Lisboa, Portugal, June-July 2004.

**Pedro M. Q. Aguiar –** Member of the Program Committee of the IEEE Multimedia Signal Processing Workshop, Siena, Italy, September 2004.

**Pedro M. Q. Aguiar –** Member of the Program Committee of the IEEE International Conference on Image Processing, Singapore, October 2004.

**Pedro M. Q. Aguiar –** Member of the Organizing Committee – Publications chair - of the IEEE Signal Processing Advances in Wireless Communications, Lisbon, Portugal, July 2004.

**Sérgio M. Jesus** - Permanent Member of the Scientific Committee of the European Conference on Underwater Acoustics, Delft, The Netherlands, July 2004.

**Victor Barroso –** General Chair of the 5th IEEE Signal Processing Advances in Wireless Communications, Lisboa, Portugal, July 2004.

### *3.6.4 CHAIRPERSON*

**M. Isabel Ribeiro –** Chair of the session "Mobile Robot Navigation I" on the 8th Conference on Intelligent Autonomous Systems – IAS8, Amsterdam, Netherlands, March 2004.

**Jorge S. Marques –** Chairman of Object Detection and Tracking session, Workshop on Image Analysis for Multimedia Interactive Services (WIAMIS), Lisbon, April 2004.

**Carlos Pinto-Ferreira –** Co-chair of ACE2004: Afective Computational Entities session of Seventeenth European Meeting on Cybernetics and Systems Research (EMCSR'2004), Vienna, Austria, 13-16 April 2004.

**Rodrigo Ventura** - Co-chair of ACE2004: Afective Computational Entities session of Seventeenth European Meeting on Cybernetics and Systems Research (EMCSR'2004), Vienna, Austria, 13-16 April 2004.

**João Sequeira –** Chair of the session "FP2-M, Algorithms and Protocols for Cooperation Amongst Unmanned Autonomous Vehicles", IROS 2004, Sendai, Japan, October 2004.

**S. M. Jesus –** Chair of the 2nd Workshop on "Acoustic Inversion Methods and Experiments for Assessment of the Shallow Water Environment", Iscia, Italy, June 2004.

**Agostinho Rosa** – Chair of the session on Sleep Fragmentation – Congresso Latino-Americano do Sono – Montevideo, Uruguay, November 2004.

**António Pascoal** - Chaired one Special Session on the DARPA Grand Challenge at the 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles (IAV 2004), Lisbon, Portugal, July 2004.

### *3.6.5 REVIEWERS*

**Agostinho Rosa** - IEEE Transaction of Biomedical Engineering.

**Agostinho Rosa** - Journal of Heuristics.

**Agostinho Rosa** - Pattern Recognition Letters.

**Agostinho Rosa** - IEEE Transaction of Circuits and Systems for Video Technology.

**Agostinho Rosa** - Clinical Neurophysiology.

**Agostinho Rosa** - International Journal of Imaging and Graphics.

**Agostinho Rosa** – Sleep.

**Agostinho Rosa** - Sleep Medicine.

**Alberto Vale** - ICRA 2005 – IEEE International Conference on Robotics & Automation.

**Alberto Vale** - IAV 2004 – 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles.

**Alexandre Bernardino** - IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**Alexandre Bernardino** - BMVC 2004 - British Machine Vision Conference.

**Alexandre Bernardino** - EPIROB 2004 - Epigenetic Robotics Workshop.

**Alexandre Bernardino** - Adaptive Behavior - Special Issue on Epigenetic Robotics.

**Alexandre Bernardino** - ACCV 2004 - Asian Conference on Computer Vision.

**Francisco Garcia** - IEEE Signal Processing Letters.

**Francisco Garcia** - IEEE Transactions on Signal Processing.

**Francisco Melo** - ICRA 2005 – IEEE International Conference on Robotics & Automation.

**Francisco Melo** - IAV 2004 – 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles.

**Isabel M. G. Lourtie** - IEEE Signal Processing Letters.

**João Gomes** - IEEE Transactions on Signal Processing, IEEE Signal Processing Letters.

**João Gomes** - IEEE Journal of Oceanic Engineering.

**João Gomes** - 5th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC'04).

**João Gomes** - Project reviewer for Fundação para a Ciência e a Tecnologia (FCT).

**João Sequeira** - IAV 2004 – 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles.

**João Sequeira** - ICARV 2004 – The 8th International Conference on Control, Automation, Robotics and Vision.

**João Sequeira** – ACC04 – American Control Conference, Boston MA, USA.

**João Sequeira** - IAS8 - 8th Conference on Intelligent Autonomous Systems, Amsterdam, Netherlands.

**João Sequeira** - IROS 2004 – IEEE/RSJ International Conference on Intelligent Robots and Systems.

**João Sequeira** - ICRA 2005 – IEEE International Conference on Robotics & Automation.

**João Sequeira** - ICINCO 2004 - International Conference on Informatics in Control, Automation and Robotics.

**João Sequeira** - ICAR 2005 - 12th IEEE International Conference on Advanced Robotics.

**João Xavier** – IEEE Transactions on Signal Processing.

**Jorge S. Marques** – WIAMIS - Workshop on Image Analysis for Multimedia Interactive Services.

**José A. Gaspar** - CVPR'04 - IEEE Computer Society Conf. on Computer Vision and Pattern Recognition.

**José A. Gaspar** IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**José A. Gaspar** – ICIP - International Conference on Image Processing.

**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** - Journal of Robotics and Autonomous Systems.

**José Santos-Victor** - IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**José Santos-Victor** - BMVC 2004 - British Machine Vision Conference.

**José Santos-Victor** - CVPR'04 - IEEE Computer Society Conf. on Computer Vision and Pattern Recognition.

**Luís Custódio** – IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**Luís Custódio** – IAS8 – 8th Conference on Intelligent Autonomous Systems.

**Luís Custódio** - AISB 2004 - Convention of the Society of Artificial Intelligence and the Simulation of Behaviour, Symposium on Emotion, Cognition and Affective Computing.

**Luís Custódio** - ICINCO 2004 - International Conference on Informatics in Control, Automation and Robotics,.

**M. Isabel Ribeiro** – Journal of Robotics and Autonomous Systems.

**M. Isabel Ribeiro** - ICAR2005 - 12th IEEE International Conference on Advanced Robotics.

**M. Isabel Ribeiro** - 16th IFAC World Congress 2005.

**M. Isabel Ribeiro** - 2004 CCA/ISIC/CASSD – IEEE Conference on Control Applications, International Symposium on Intelligent Control, Computer Aided Control of Systems-Design.

**M. Isabel Ribeiro** - IAV2004 – 5th IFAC/Euron Symposium on Intelligent Autonomous Vehicles.

**M. Isabel Ribeiro** - RoMoCo04 – 4th International Workshop on Robot Motion and Control.

**M. Isabel Ribeiro** - IAS8 - 8th Conference on Intelligent Autonomous Systems.

**M. Isabel Ribeiro** - ROBÓTICA2004 – Festival Nacional de Robótica.

**M. Isabel Ribeiro** - CONTROLO2004 – Portuguese Conference on Automatic Control.

**M. Isabel Ribeiro** - IROS2004 – IEEE/RSJ International Conference on Intelligent Robots and Systems.

**M. Isabel Ribeiro** - ICRA2005 – IEEE International Conference on Robotics & Automation.

**Pedro Lima** – Elsevier Journal of Robotics and Autonomous Systems.

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

**Pedro Lima** – IFAC World Congress 2005.

**Pedro Lima –** ICAR 2005 - 12th International Conference on Advanced Robotics.

**Pedro Lima –** ICRA 2005 **-** IEEE International Conference on Robotics and Automation.

**Pedro Lima –** MIC 2004 - IASTED International Conference on Modelling, Identification and Control.

**Pedro Lima –** IAS8 - 8th Conference on Intelligent Autonomous Systems.

**Pedro Lima** – IAV 2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**Pedro Lima** – ACC'2004 e ACC'2005 - American Control Conference.

**Pedro Lima** – IROS 2004 - IEEE/RSJ Intelligent Robotic Systems.

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

**Pedro M. Q. Aguiar** - IEEE Multimedia Signal Processing Workshop.

**Pedro M. Q. Aguiar** - IEEE Signal Processing Letters.

**Pedro M. Q. Aguiar** - IEEE Transaction on Image Processing.

**Rodrigo Ventura -** SAC05 - 20th Annual ACM Symposium on Applied Computing.

**Rodrigo Ventura** – IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**Sérgio M.Jesus** - Journal of Acoustical Society of America.

**Sérgio M.Jesus** - IEEE Journal of Oceanic Engineering.

**Sérgio M.Jesus** – ICASSP 2004 - IEEE International Conference on Acoustics, Speech and Signal Processing.

**Sérgio M.Jesus** - ECUA'04 – 7th European Conference on Underwater Acoustics.

**Victor Barroso -** ICASSP 2004 - IEEE International Conference on Acoustics, Speech and Signal Processing.

**Victor Barroso** - IEEE International Workshop on Sensor Array and Multichannel Signal Processing.

**António Pascoal –** Automatica.

**António Pascoal** - IEEE Journal of Oceanic Engineering.

**António Pascoal** - Journal of Engineering for the Maritime Environment.

**António Pascoal** - Advanced Robotics, the Journal of the Robotics Society of Japan.

**António Pascoal -** CAMS 2004 - IFAC Conference on Control Applications in Marine Systems.

**António Pascoal** - CCA 04 - IEEE Conference on Control Applications.

**António Pascoal –** CDC 2004 - 43rd Conference on Decision and Control.

**António Pascoal –** IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**António Pascoal -** IROS 2004 - IEEE/RSJ International Conference on Intelligent Robots and Systems.

**António Pascoal –** ACC'04 – Automatic Control Conference.

**António Pascoal** - MED 2004 - Mediterrranean Control Conference.

**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 -** IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

**Carlos Silvestre -** IEEE International Conference on Mechatronics & Robotics 2004.

**Carlos Silvestre -** CDC 2004 **-** 43rd IEEE Conference on Decision and Control.

**Paulo Oliveira –** 16th IFAC World Congress.

**Paulo Oliveira –** CDC 2004 - 43rd Conference on Decision and Control.

**Paulo Oliveira –** 2004 National Robotics Meeting.

**Paulo Oliveira –** 2004 CCA/ISIC/CACSD.

**Paulo Oliveira –** CAMS 2004 - IFAC Conference on Control Applications in Marine Systems.

**Paulo Oliveira –** IAV 2004 – 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles.

### *3.6.6 OTHER ACTIVITIES*

**Agostinho Rosa** - Evaluator of Programme "Marie Curie – Excellence Chair".

**Francisco Garcia** - Member of the Executive Board of IST's Dept. of Electrical and Computer Engineering.

**João Gomes** - Administrator of ISR signal processing laboratory computing resources.

**M. Isabel Ribeiro –** Adjunct Director for Project Management, IST.

**Pedro Lima** - Co-editor (with Prof. F. Groen, University of Amsterdam) of a special issue on "Multi-Robots in Dynamic Environments" of Elsevier's Journal of Robotics and Autonomous Systems, Vol 50/2-3, 2005.

**Pedro Lima –** Reviewer of Ph.D. Thesis of Alessandro Farinelli, University of Rome "La Sapienza".

**Pedro Lima –** Author of the articles "O que é um Robot? Como se classificam os robots?" and "Aplicações dos Robots: para que servem os robots?", for the *Enciclopédia Activa Multimédia*, Volume *Tecnologias*, Lexicultural.

**Pedro M. Q. Aguiar** - Member of the Scientific Committee of the IST ECE Graduate Education -- coordinator of the Systems, Decision, and Control Area.

**Victor Barroso –** Vice-President of the IST's Scientific Council.

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

## *3.7 ACADEMIC ACTIVITIES*

Here we list the participation, during 2004, of ISR-Lisbon (ECE) researchers in committees for Master and Doctoral Thesis, and other academic related activities.

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

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

**Pedro Lima** – Member of the Ph.D. Thesis Committee of Armando Jorge Miranda de Sousa, "Localização em Tempo Real de Múltiplos Robots num Ambiente Dinâmico", Faculdade de Engenharia, Universidade do Porto, July 2004.

**Pedro Lima** – Member of the Ph.D. Thesis Committe of Dejan Milutinovic, "Stochastic Model of Micro-Agent Populations", Instituto Superior Técnico, Universidade Técnica de Lisboa, September 2004 – Supervisor.

**Luís Custódio** – Member of Coordenation Committee of the Electrical and Computer Engineering (LEEC) undergraduated degree, at IST. Coordinator of the LEEC's branch on Systems, Decision and Control.

**Luís Custódio** – Member of the Ph.D. Thesis Committee of Fernando Jorge Ferreira Lopes, "Negociação entre Agentes Computacionais Autónomos", November 2004.

**Luís Custódio** – Member of the Master Thesis Committee of Rui Miguel Dias Carvalho, "Concepção de um Sistema Multi-Agente para a Resolução de Problemas de Cadeias de Produção-Distribuição", October 2004 – Supervisor.

**José Santos-Victor** - Member of the PhD Thesis Committee of João Pedro Barreto, "Sistemas Centralizados de Projecção Central," Departamento de Engenharia Electrotécnica e de Computadores, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, January 2004.

**João Paulo Costeira** - Member of the Ph.D. Thesis Committee of João Pedro Barreto, "Sistemas Centralizados de Projecção Central," Departamento de Engenharia Electrotécnica e de Computadores, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, January 2004.

**José Santos-Victor** - Member of the Ph.D. Thesis Committee of Alexandre José Malheiro Bernardino, "Binocular Head Control with Foveal Vision: Methods and Applications," IST, April de 2004 – Supervisor.

**José Santos-Victor** - Member of the Ph.D. Thesis Committee of Xavier Lladó Bardera, "Texture recognition under varying imaging geometries," Departamento de Electrónica, Informática e Controlo Automático, Universitat de Girona, Spain, February 2004.

**José Santos-Victor** - Member of the Ph.D. Thesis Committee of Raquel Frizzera Vassallo. "Uso de mapeamentos visuomotores com imagens omnidireccionais para aprendizagem por imitação em robótica," Ph.D. Thesis, Universidade Federal do Espírito Santo, UFES, Brasil, September 2004.

**José Santos-Victor** - Member of the Ph.D. Thesis Committee of Anthony Remazeilles. "Navigation a partir d'une memoire d'images," Ph.D. Thesis, IRISA/INRIA, Université de Rennes, França, December 2004.

**José Santos-Victor** - Member of the M.Sc. Thesis Committee of AlpeshKumar Narotam Ranchordas. "Um Sistema de Realidade Aumentada sem Calibração," M.Sc. Thesis, IST, May 2004.

**José Santos-Victor** - Member of the M.Sc. Thesis Committee of Maria da Graça Vieira de Brito Almeida, "Controlo de um manipulador robótico usando visão", M.Sc Thesis, IST, September 2004 - Supervisor.

**José Gaspar** - Member of the M.Sc. Thesis Committee of AlpeshKumar Narotam Ranchordas. "Um Sistema de Realidade Aumentada sem Calibração," M.Sc. Thesis, IST, May 2004.

**João Sentieiro** – Member of the Ph.D. Thesis Committee of Alexandre José Malheiro Bernardino, "Binocular Head Control with Foveal Vision: Methods and Applications," IST, April de 2004.

**M. Isabel Ribeiro** – Vice-Director of the Institute for Systems and Robotics / Lisbon pole.

**M. Isabel Ribeiro** – Member of the Ph.D. Thesis Committee of José Eduardo Charters Ribeiro da Cunha Sanguino, "Binocular Head Control with Foveal Vision: Methods and Applications", Instituto Superior Técnico, April 2004 – Examinor.

**M. Isabel Ribeiro** – Member of the Ph.D. Thesis Committee of Alexandre José Malheiro Bernardino, "Range-Aided Dead Reckoning with Unknown Departure Point", Instituto Superior Técnico, September 2004 - Examinor.

**João Sequeira** – Member of the M.Sc. Thesis Committee of Sandra Maria Santos de Sousa Aires, "Análise de Ondas Móveis em Campos Neuronais", Universidade do Minho, Portugal, February 2004 – Examinor.

**Victor Barroso –** Member of the Ph.D. Thesis Committee, Paulo Alexandre Carapinha Marques, "Moving Objects Imagingand Trajectory Estimation Using a Single Synthetic Aperture Radar Sensor", IST-UTL, 2004.

**Victor Barroso –** Member of the Ph.D. Thesis Committee, João Miguel Pissarra Coelho Gil, "Dependencies of Adaptive Beamforming on the Propagation Channel in Wideband Mobile Communications" IST-UTL, 2004.

**Victor Barroso –** Member of the Ph.D. Thesis Committee, Jorge Augusto Castro Neves Barbosa, "Compressão de Video para Aplicações Submarinas", IST-UTL, 2004.

**Victor Barroso** – Member of the M.Sc. Thesis Committee of Paulo Lopes, "Bayesian Signal Reconstruction in Wireless Communication Systems with Spatial Diversity", Instituto Superior Técnico, Universidade Técnica de Lisboa, April 2004.

**Victor Barroso** – Member of the M.Sc. Thesis Committee of Manuel Augusto Vieira, "Melhoria da Velocidade dos Transportes Públicos de Superfície em Lisboa por Regulação da Admissão de Trânsito", IST-UTL, 2004.

**Pedro M. Q. Aguiar** – Member of the Ph.D. Thesis Committee of Pei Chen, "An Investigation of Statistical Aspects of Linear Subspace Analysis for Computer Vision Applications", Monash University, Australia, 2004.

**Pedro M. Q. Aguiar** – Member of the Ph.D. Thesis Committee, Jorge Barbosa, "Compressão de Video para Aplicações Submarina", IST, February 2004.

**Pedro M. Q. Aguiar** – Member of the M.Sc. Thesis Committee, Rui Guerreiro, "Modelos 3D Densos a partir de Imagens com Sobreposição Parcial: Factorização com Dados Desconhecidos", IST, September 2004.

**João Xavier** – Member of the MSc Thesis Committee of Paulo Lopes, "Bayesian Signal Reconstruction in Wireless Communication Systems with Spatial Diversity", Instituto Superior Técnico, Universidade Técnica de Lisboa, April 2004.

**Jorge S. Marques** – Member of the M.Sc. Thesis Committee, Liliana Matos Pereira, "Estimação: Métodos Paramétricos Clássicos vs Redes Neuronais", Departamento de Matemática Aplicada, Faculdade de Ciências da Universidade do Porto, January 2004.

**Jorge S. Marques** – Member of the M.Sc. Thesis Committee, Pedro Fonseca, "Detecção de Faces e Seguimento de Objectos em Domínio Comprimido", Instituto Superior Técnico, June 2004.

**Jorge S. Marques –** Member of the Ph.D. Thesis Committee, Carla Pereira, "Reconhecimento de Padrões. Classificação Supervisionada com Rejeição de Observações", Departamento de Matemática, Instituto Superior Técnico, December 2004.

**João Gomes –** Co-advisor and Member of the Ph.D. Thesis Committee of António João Freitas G. da Silva, "Time-reversed underwater communications", Universidade do Algarve.

**Carlos Silvestre -** Member of the Msc Thesis Committee - "The Life System: An augmented reality visualization of biomechanics data", Department of Informatics, Instituto Superior Técnico, Lisbon, Portugal.

**Carlos Silvestre** - Member of the Msc Thesis Committee - "An architecture for large scale distributed virtual environments in the internet", Department of Informatics, Instituto Superior Técnico, Lisbon, Portugal.

**António Pascoal -** Member, Committee for the promotion of tenured Associate Professor Edgar An to the rank of Professor, Department of Ocean Engineering, Florida Atlantic University, Dania Beach, FL, USA.

**António Pascoal** - Member, Committee for the promotion of tenured Associate Professor Isaac Kaminer to the rank of Professor, Dept. Mechanical and Aeronautical Engineering, Naval Postgraduate School, Monterey, California, USA.

## *3.8 DISTINGUISHED VISITORS*

**Prof. Giulio Sandini** - DIST, University of Genova, Italy.

**Prof. François Chaumette** - IRISA, France.

**Prof. Robert E. Fisher** - University of Edimburgh, UK.

**Pramod Kumar Maurya -** Division of the National Institute of Oceanography (NIO), Dona Paula, Goa, India.

**Shivanand P. Prabhudesai** (Head of Division) - Division of the National Institute of Oceanography (NIO), Dona Paula, Goa, India.

**Prof. Thor Fossen** - NTNU, Trondheim, Norway.

**Prof. Olav Egeland** - NTNU, Trondheim, Norway.

**Prof. Anthony Healey** - Naval Postgraduate School, Monterey, California, USA.

**Marcus Cardew** – System Technologies.

## *3.9 SPECIAL EVENTS*

### 3.9.1 ROBOCUP2004

**Instituto Superior Técnico, Lisboa, Portugal**
**27 June – 5 July, 2004**

**Coordinators:** Pedro Lima, Luís Custódio
**Laboratories:** Intelligent Systems Lab
**Support:** RoboCup Federation, Fundação para a Ciência e a Tecnologia (FCT), Agência Nacional para a Cultura Científica e Tecnológica – Ciência Viva, Turismo de Lisboa, Record, Viking Telecom, Exame Informática, ICEP Portugal, TAP Air Portugal.
**Description:** RoboCup is an international initiative with the main goals of fostering research and education in Artificial Intelligence and Robotics, as well as of promoting Science and Technology to world citizens. The idea is to provide a standard problem where a wide range of technologies can be integrated and examined, as well as being used for integrated project-oriented education, and to organize annual events open to the general public, where different solutions to that problem are compared. As in past years, RoboCup2004 consisted of the 8th Symposium and of the Competitions. The competitions took place at the Pavilion 4 of Lisbon International Fair (FIL), an exhibition hall of approximately 10 000 m², located at the former site of Lisbon EXPO98 world exhibition. The Symposium was held at the Congress Center of the Instituto Superior Técnico (IST), Lisbon Technical University. Together with the competitions, two regular demonstrations took place on a daily basis: SegWay soccer, by a team from Carnegie-Mellon University, coordinated by Prof. Manuela Veloso, and SONY QRIO robot, by a team from SONY Japan. RoboCup2004 was locally organized by a Portuguese committee composed of 15 researchers and University professors from several Universities, therefore underlining the national nature of the event organization. This committee worked closely with the international organizing and technical committees to set up an event with the record number of 1627 participants from 37 countries, and an estimated number of 500 robots, split by 346 teams.
**URL:** http://www.robocup2004.pt/

### 3.9.2 ROBOCUP SYMPOSIUM 2004

**Instituto Superior Técnico, Lisboa, Portugal**
**4 July – 5 July 2004**

**Coordinator:** José Santos-Victor
**Description:** The RoboCup 2004 Symposium took place at the Instituto Superior Técnico, in Lisbon, Portugal in conjunction with the RoboCup competition. A problem in any branch of science or engineering is how to devise tests that can provide objective comparisons between alternative methods. In recent years, competitive engineering challenges have been established to motivate researchers to tackle difficult problems while providing a framework for the comparison of results. RoboCup was one of the first of such competitions and has been a model for the organisation of challenges following sound scientific principles. In addition to the competition, the associated symposium provided a forum for researchers to present refereed papers. But for RoboCup, the symposium had the greater goal of encouraging the exchange of ideas between teams so that the competition, as whole, progresses from year to year and strengthens it's contribution to robotics. 118 papers were submitted to the Symposium. Each paper was reviewed by at least two international referees. 30 papers were accepted for presentation at the Symposium as full papers and a further 38 were accepted for poster presentation.

The Symposium was co-located with the 5th IFAC/EURON International Symposium on Intelligent Autonomous Vehicles (IAV2004) and featured four distinguished plenary speakers: Hugh Durrant-Whyte, Luigia Carlucci Aiello, James Albus, Shigeo Hirose. The program included a discussion panel on Applications of

RoboCup Research. The members of the panel were Hiroaki Kitano, Christian Philippe (ESTEC/ESA) and M. Isabel Ribeiro (ISR/IST) and was organised and moderated by Hans-Dieter Burkhard.

### 3.9.3 3rd ISlab WORKSHOP

**Instituto Superior Técnico, Lisboa, Portugal**
**February 13, 2004**

**Coordinator:** Rodrigo Ventura
**Laboratories:** Intelligent Systems Laboratory
**Description:** This was a workshop organized by the Intelligent Systems Lab, aiming at the presentation for all the group of the research work being developed by its members, mainly the Ph.D. and M.Sc. students.
**URL:** http://islab.isr.ist.utl.pt/htdocs/workshop3/index.html

### 3.9.4 4th ISlab WORKSHOP

**Instituto Superior Técnico, Lisboa, Portugal**
**November 12, 2004**

**Coordinator:** Gonçalo Neto
**Laboratories:** Intelligent Systems Laboratory
**Description:** This was a workshop organized by the Intelligent Systems Lab. aiming at the presentation for all the group of the research work being developed by its members, mainly the Ph.D. and M.Sc. students.
**URL:** http://islab.isr.ist.utl.pt/htdocs/workshop4/index.html

### 3.9.5 IAV2004 – 5th IFAC/EURON SYMPOSIUM ON INTELLIGENT AUTONOMOUS VEHICLES

**Instituto Superior Técnico, Lisboa, Portugal**
**July 5 – July 7, 2004**
**http://iav04.isr.ist.utl.pt**

This Symposium was the fifth of a series of IFAC-sponsored meetings in the field of Intelligent Autonomous Vehicles. Previous symposia were held in the United Kingdom (1993), Finland (1995), Spain (1998) and Japan (2001). In 2004, IAV2004 was organized by the Institute for Systems and Robotics (ISR) / Instituto Superior Técnico (IST), with the sponsorship of IFAC-International Federation of Automatic Control and EURON-European Robotics Research Network, and was held at the Congress Hall on the campus of the Instituto Superior Técnico July 5-7, 2004.

The call for papers for IAV2004 elicited a record number of 227 submissions from all over the world. The International Program Committee and a set of external reviewers carried out a very thorough and objective assessment of the papers' technical quality and suitability for presentation at the symposium. Because of their valuable work, it was possible for 99% of the papers to receive at least two independent assessments, and for 78% to receive three reviews. Papers submitted to invited sessions were subject to the same review process as regular papers. A total of 165 papers were accepted for presentation.

The technical program of IAV2004 included 6 plenary invited lectures, 5 invited sessions with a total of 30 papers, and 26 regular sessions. IAV2004 was coordinated with the RoboCup Symposium, also organized by ISR/IST, and both events shared the plenary lectures on Monday, July 5. IAV2004 was attended by 210 participants.

The IAV2004 Preprints were published as a CD-ROM distributed to all the registered participants. The presented papers are included in the IAV2004 Proceedings to be published by Elsevier Science (ISBN 008 044237 4).

**GENERAL CHAIR:**

M. Isabel Ribeiro, Institute for Systems and Robotics/IST, Portugal

**CHAIRS OF THE IPC (members of the ISR/IST)**

**Chair:** M. Isabel Ribeiro, Institute for Systems and Robotics/IST, Portugal
**Vice-Chair:** António Pascoal, Institute for Systems and Robotics/IST, Portugal

**EDITORS**

M. Isabel Ribeiro, Institute for Systems and Robotics/IST, Portugal
José Santos-Victor, Institute for Systems and Robotics/IST, Portugal

**NATIONAL ORGANIZING COMMITTEE (members of ISR/IST)**

**Chair:** Carlos Silvestre, Institute for Systems and Robotics/IST, Portugal
José Santos-Victor, Institute for Systems and Robotics/IST, Portugal
João Paulo Costeira, Institute for Systems and Robotics/IST, Portugal
Alexandre Bernardino, Institute for Systems and Robotics/IST, Portugal

**INVITED SPEAKERS:**

James Albus, National Institute of Standards and Technology, USA
Shigeo Hirose, Tokyo Institute of Technology, Japan
Gianmarco Veruggio, CNR-Robotlab, Italy
Samad Hayati, Jet Propulsion Lab, USA
George Vachtsevanos, Georgia Institute of Technology, USA
Raja Chatila, LAAS-CNRS, France

### 3.9.6 MARITIME RAPID ENVIRONMENTAL ASSESSMENT'04 SEA TRIAL

**Continental Shelf off Setúbal, Portugal**
**April 7 – 10, 2004**

Field experiment: participation in the Maritime Rapid Environmental Assessment'04 sea trial, organized by the NATO Undersea Research Centre (NURC), La Spezia (ITALY), from March 26 - April 11, 2004, off the west coast of Portugal, near Setubal. This participation is made under the AOB-Joint Research Project involving SiPLAB, NURC, ULB (Belgium), IH (Portugal) and RNLNC (The Netherlands).

### 3.9.7 ACOUSTIC TOMOGRAPHIC MONITORING SYSTEM'04 SEA TRIAL

**Off Cape São Vicente, SW Portugal**
**October 2 – 25, 2004**

Field experiment: participation in the Acoustic Tomographic Monitoring System - ATOMS'04 sea trial, organized by the Instituto Hidrografico, Liboa (Portugal) from October 2 - 25, 2004, off the soutwest coast of Portugal, near Cape S. Vicent. This participation is made under the ATOMS Project involving SiPLAB, EST and CIMA from University of Algarve.

### 3.9.8 SPAWC –5TH IEEE INTERNATIONAL WORKSHOP ON SIGNAL PROCESSING ADVANCES FOR WIRELESS COMMUNICATIONS

**Instituto Superior Técnico, Lisboa, Portugal**
**11-14 July, 2004**
**http://spawc2004.isr.ist.utl.pt/**

SPAWC-2004, the fifth IEEE International Workshop on Signal Processing Advances for Wireless Communications, was devoted to recent advances in signal processing for wireless and mobile communications. This workshop brings together members of the signal processing, communications and information theory communities, working in universities, research centers and telecommunications companies. The meeting featured keynote addresses by leading researchers, as well as invited and contributed papers.

SPAWC-2004 was held at Hotel Tivoli - Tejo, in Lisbon, Portugal, more precisely at the Parque das Nações. This site offers some of the most daring examples of contemporary architecture, Europe's largest Oceanarium, delightful thematic gardens, exhibition centers, theaters and event halls, all located along a breathtaking 5 km stretch of the Tagus riverfront, in the heart of Lisbon, benefiting from a wide array of shops, restaurants and bars. Only five minutes from Lisbon International Airport, Parque das Nações builds on the heritage of EXPO'98 - the last world exposition of the twentieth century.

## *3.10 AWARDS and PATENTS*

- **AWARDS**

Best Poster Award of Intelligent Autonomous Systems IAS-8, Amsterdam, The Netherlands, March 2004: "Bayesian Sensor Fusion for Cooperative Object Localization", **Pedro Pinheiro** e **Pedro Lima.**

- **PATENTS**

"*A Controlled Thruster-Driven Profiler for Coastal Waters*", Elgar Desa, **A.Pascoal,** Ehrlich Desa, P.Mehra, R.Madhan, G.P.Naik, US patent Number 6786087 sept 7, 2004. The patent is the outcome of joint work done by IST/ISR and the NIO, Goa, India.

## *3.11 PUBLICATIONS*

**A) M.Sc. THESES (8):**

[1] **Paulo Lopes**, "Bayesian Signal Reconstruction in Wireless Communication Systems with Spatial Diversity", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, April 2004.

[2] **Alpeshkumar Narotam Ranchordas**, "Um Sistema de Realidade Aumentada sem Calibração", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2004.

[3] **Havard Bo**, "Hydrodynamic Estimation and Identification", Department of Engineering Cybernetics/ NTNU, Trondheim, Master Thesis, Norway and Instituto Superior Técnico /ISR , Lisbon, Portugal, August 2004.

[4] **Christian Skaar**, "Coordination Motion Control", Department of Engineering Cybernetics/NTNU, Master Thesis, Trondheim, Norway and Instituto Superior Técnico /ISR , Lisbon, Portugal, August 2004.

[5] **Rui F. C. Guerreiro**, "Modelos 3D densos a partir de imagens com sobreposição parcial: factorização com dados desconhecidos", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, September 2004.

[6] **Maria da Graça Vieira de Brito Almeida,** "Controlo de um Manipulador Robótico Usando Visão", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, September, 2004.

[7] **Pedro Alves**, "Nonlinear Target Tracking", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2004.

[8] **Rui Miguel Dias Carvalho**, "Concepção de um Sistema Multi-Agente para a Resolução de Problemas de Cadeias de Produção-Distribuição", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2004.

**B) Ph.D. THESES (3):**

[9] **Dejan Milutinovic**, "Stochastic Model of Micro-Agent Populations", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2004.

[10] **Alexandre Bernardino**, "Binocular Head Control with Foveal Vision : Methods and Applications", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, April 2004.

[11] **Raquel Frizera Vassallo**, "Uso de Mapeamentos Visuomotores com Imagens Omnidireccionais para Aprendizagem por Imitação em Robótica", Ph.D. Thesis, Universidade Federal do Espírito Santo, Vitória, Espírito Santo, Brasil, September 2004.

**C) IN BOOKS (6):**

[12] **G. Neto, H. Costelha, P. Lima**, "Topological Navigation in Configuration Space Applied to Soccer Robots", RoboCup-2003: Robot Soccer World Cup VII, Springer Verlag, Berlin, 2004.

[13] **H. Lausen, J. Nielsen, M. Nielsen, P. Lima**, "Model and Behavior-Based Robotic Goalkeeper", RoboCup-2003: Robot Soccer World Cup VII, Springer Verlag, Berlin, 2004.

[14] **M. Isabel Ribeiro**, "Robots Móveis", Enciclopédia Activa Multimédia, volume de Tecnologias, Lexicultural, pp. 226-227, October 2004.

[15] **M. Isabel Ribeiro**, "Sensores em Robótica", Enciclopédia Activa Multimédia, volume de Tecnologias, Lexicultural, pp. 228-229, October 2004.

[16] **M. Isabel Ribeiro**, "Navegação em Robótica Autónoma", Enciclopédia Activa Multimédia, volume de Tecnologias, Lexicultural, pp.232-233, October 2004.

[17] **Pedro M. Q. Aguiar, Radu S. Jasinschi, José M. F. Moura, and Charnchai Pluempitiwiriyawej**, "Content-based Image Sequence Representation", in Digital Image Sequence Processing, Compression and Analysis, CRC Press, August 2004.

## D) IN INTERNATIONAL JOURNALS (26)

[18] **J. Hespanha, O. Yakimenko, I. Kaminer , A. Pascoal**, "Linear Parametrically Varying Systems with Brief Instabilities: An Application to Integrated Vision/IMU Navigation", *IEEE Trans. Aerospace and Electronic Systems*, Vol. 40, N0. 3, pp. 889-9902, 2004.

[19] **C. Silvestre, A. Pascoal**, "Control of the Infante AUV using Gain-Scheduled Static Output Feedback," IFAC Journal *Control Engineering Practice*, Vol. 12&12, pp. 1501-1509, 2004.

[20] **P. Tabuada, G. Pappas and P. Lima**, "Compositional Abstractions of Hybrid Control Systems", *Journal of Discrete Event Dynamic Systems*, Volume 14, Issue 2, April 2004.

[21] **P. Lima, L. Custódio**, "Artificial Intelligence and Systems Theory Applied to Cooperative Robots", *International Journal of Advanced Robotic Systems*, No. 3, September 2004.

[22] **C. Marques, P. Lima**, "Multi-Sensor Navigation for Non-Holonomic Robots in Cluttered Environments", *IEEE Robotics and Automation Magazine*, 11(3), September 2004.

[23] **J. Buescu, A. C. Paixão, F. M. Garcia and I. M. G. Lourtie**, "Positive-Definiteness, Integral Equations and Fourier Transforms", *Journal of Integral Equations and Applications*, vol. 16, no. 1, Spring 2004.

[24] **F. M. Garcia and I. M. G. Lourtie**, "Detection of Transient Signals with Unknown Localization", *IEEE Signal Processing Letters*, vol. 11, no. 9, September 2004.

[25] **Jacinto Nascimento, Jorge S. Marques**, "Robust Shape Tracking in the Presence of Cluttered Background", *IEEE Transactions on Multimedia,* Vol. 6, no. 6, December 2004.

[26] **Gilles Celeux, Jorge S. Marques, Jacinto Nascimento**, "Learning Switching Dynamic Models for ObjectsTracking", *Pattern Recognition*, vol. 37, nº 9, 1835-1840, September 2004.

[27] **P. Lopes, J. Xavier, V. Barroso**, "Blind Source Separation and Channel Identification: Exploiting 2nd Order Statistics in Bayesian Frameworks", *Journal of the BrazilianTelecommunications Society* (JTBS).

[28] **Teresa Paiva, Thomas Penzel, Juergen Zulley, Colin Binnie, Michel Russel, Pierre Escourrou, Madalena Teles Araujo, Ana Fred, Alpo Varri, Mafred Spreng, Kim Nielsen, Carlos Belo, Agostinho Rosa and Christian Guilleminault**, "The ENN Project – A Telematics Experience in Neurology", *Somnology* 8:3-13, February 2004.

[29] **C. Munteanu, A. C. Rosa**, "Gray-Scale Image Enhancement as an Automatic Process driven by Evolution", *IEEE Transactions on Systems Man and Cybernetics – Part B*, vol. 34 No. 2, pp 1292-1298, April 2004.

[30] **C. Munteanu, A. C. Rosa**, "Adaptive Reservoir Evolutionary Algorithm: An evolutionary on-line adaptation scheme for global function optimization", *Journal of Heuristics*, 10, pp 555-586, 2004.

[31] **Mello-Fujita LIL, Roizenblatt S, Poyares DL, Rosa AC, Conway S, Almeida TF, Tufik S.**, "Sleep-related respiratory disorders in patients with Gastroesophageal Reflux symptoms, A clinical populational study", *Sleep*, vol 27, A212, AS 2004.

[32] **Poyares D., Cintra F.D., Guilleminault C., De Marchi G., Barreto S., Roizenblatt S., Rosa, A. C., Tufik S., De Paola A. A. V.**, "Heart rate variability during REM and Non REM sleep in patients with eurocardiogenic syncope", *Sleep,* vol 27, A331-2, AS 2004.

[33] **Roizenblat, S., Passareli CM, Len C. A., Moreira G., Terreri M. T., Rosa, A. C., Hilario M. O., Tufik, S.,** "The impact of pain and dysfunction in sleep of children with polyarticular juvenile idiopathic arthritis", *Journal of Sleep Research*, vol 13, S1, September 2004.

[34] **Lopes-Conceição, M. C., Roizenblat, S., Poyares, D., Rosa, A. C., Passarelli, C. Tufik, S., "**Sleep cyclic alternating pattern in normal children", *Journal of Sleep Research*, vol 13, S1, September 2004.

[35] **Luciane Mello Fujita, Suely Roizenblatt, Dalva Poyares, Cláudio Frison, Lia Bittencourt, Lino Rodrigues Jr, Agostinho Rosa, Sérgio Tufik**, "The Impact of GER in Sleep of Asthmatic Patients", *Journal of Sleep Research*, 2004.

[36] **Tatiana F. Almeida, Suely Roizenblatt, Dalva Poyares, Maria Jose M. Dias, Agostinho C. Rosa, Christian Guilleminault, Sergio Tufik**, "Improvement in sleep, cognitive, psychological and symphathetic activity concomitant to tender point analgesia in fibromyalgia", *Journal of Sleep Research*, vol 13, S1, September 2004.

[37] **Agostinho Rosa, Cecília Lopes-Conceição, Tatiana Almeida, Dalva Poyares**, "High Cap Rate: A Case Report", *Journal of Sleep Research*, vol 13, S1, September 2004.

[38] **Poyares D., Guilleminault C., Rosa A. C., Almeida T., Lopes-Conceição M. C., Guimarães C., Roisenblatt S., Kirisoglu C., Tufik S.,** "Sleep EEG power spectrum and CAP in fatigue patients", *Journal of Sleep Research*, vol 13, S1, September 2004.

[39] **Rogerio Largo, Maria-Cecília Lopes, Agostinho Rosa**, "Evolutionary tuning of Automatic Classification of CAP in normal Children", *Journal of Sleep Research*, vol 13, S1, September 2004.

[40] **Felisberto P., Lopes C. and Jesus S. M.,** "An autonomous system for ocean acoustic tomography", *Sea Technology*, Vol. 45, No.4, pp. 17-23, April 2004.

[41] **Loke, R.E. and du Buf, J. M. H.**, "Quadtree-guided 3D interpolation of irregular sonar data sets", *IEEE J. of Oceanic Engineering*, 29 (2), 457-471, 2004.

[42] **Loke, R. E., du Buf, J. M. H., Bayer, M. M. and Mann, D. G.**, "Diatom classification in ecological applications", *Pattern Recognition*, 37 (6), 1283-1285, 2004.

[43] **Mann, D. G., McDonald, S. M., Bayer, M. M., Droop, S. J. M., Chepurnov, V. A., Loke, R. E., Ciobanu, A. and du Buf, J. M. H.**, "The Sellaphora pupula species complex (Bacillariophyceae): morphometric analysis, ultrastructure and mating data provide evidence for five new species", *Phycologia*, 43 (4), 459-482, 2004.

## E) IN NATIONAL JOURNALS (1)

[44] **A. Pascoal**, "Robots Marinhos para Aplicações Científicas: a Experiência do IST", *Revista Técnica*, IST, 2004.

**F) IN INTERNATIONAL CONFERENCES (66)**

[45] **A. Alcocer, P. Oliveira, A. Pascoal,** "Study and Implementation of an EKF GIB-Based Underwater Positioning System", *Proc. IFAC Conference on Control Applications in Marine Systems,* Ancona, Italy, July 2004.

[46] **E. Barros, A. Pascoal, E. De Sa**, "AUV Dynamics: Modelling and Parameter Estimation Using Analytical, Semi Empirical, and CFD Methods", *Proc. IFAC Conference on Control Applications in Marine Systems,* Ancona, Italy, July 2004.

[47] **S. Fekri, M. Athans, A. Pascoal,** "A New Robust Adaptive Control Method Using Multiple Models", *Proc. 12th IEEE Mediterranean Conference on Control and Automation,* Turkey, June 2004.

[48] **S. Fekri, M. Athans, A. Pascoal,** "RMMAC. A Novel Robust Adaptive Control Scheme – Part I: Architecture", *Proc. IEEE Conference on Decision and Control* (CDC 2004), Bahamas, December 2004.

[49] **S. Fekri, M. Athans, A. Pascoal,** "RMMAC. A Novel Robust Adaptive Control Scheme – Part II: Performance Evaluations", *Proc. IEEE Conference on Decision and Control* (CDC 2004), Bahamas, December 2004.

[50] **R. Ghabcheloo, A. Pascoal, C. Silvestre, I. Kaminer**, "Coordinated Path Following Control of Multiple Wheeled Robots", *IAV 2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles,* Lisbon, Portugal, July 2004.

[51] **G. Indiveri**, **A. Pascoal**, "A Switching Path Following Guidance Control Law for an Underactuated Marine Vehicle", *Proc. IFAC Conference on Control Applications in Marine Systems,* Ancona, Italy, July 2004.

[52] **I. Kaminer, O. Yakimenko, V. Dobrokhodov, M. Lizaraga, A. Pascoal,** "Cooperative Control of Small UAVs for Naval Applications", *Proc. IEEE Conference on Decision and Control* (CDC 2004), Bahamas, December 2004.

[53] **P. M. Sarradin, Sarrazin J., Olu K., Desbruyères D., Rigaud V., Cadiou J.F., Drogou J.F., Lecornu F., Rolin J.F., Vuillemin, R.,. Cambon-Bonavita, MA, Sauter E., von Juterzenka, K., Boetius A., R. Serrão Santos, Colaço A., Pascoal A., Oliveira P., Shillito B., Zal F., Schultz A., Taylor P., Lane D., du Buf H., Waldmann C., Cormack A., Sanfilippo L., Masson M**, "Extreme Ecosystem Studies in the Deep Ocean: Technological Developments: The EXOCET/D Project FP6-GOCE-CT-2003-505342", *Proc. of the Fourteenth International Offshore and Polar Engineering Conference*, Vol 1: 738-746, 2004.

[54] **Carlos Silvestre, Paulo Oliveira, Antonio Pascoal, Luís Gabriel Silva, João Alfredo Santos, Maria da Graça Neves**, "Inspection and Diagnosis of the Sines West Breakwater", *ICCE2004 - 29th International Conference on Coastal Engineering*, Lisbon, Portugal, September 2004.

[55] **J.F. Vasconcelos, J. Calvário, P. Oliveira, C. Silvestre,** "GPS aided IMU for Unmanned air vehicles", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles*, Lisbon Portugal, July 2004.

[56] **P. Pinheiro, P. Lima**, "Bayesian Sensor Fusion for Cooperative Object Localization and World Modeling", *Proc. 8th Conference on Intelligent Autonomous Systems* – IAS-8, Amsterdam, The Netherlands, March 2004.

[57] **B. Damas**, **P. Lima**, "Stochastic Discrete Event Model of a Multi-Robot Team Playing an Adversarial Game", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles* , Lisbon, Portugal, July 2004.

[58] **J. Frazão**, **P. Lima**, "Agent-Based Software Architecture for Multi-Robot Teams", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles* , Lisbon, Portugal, July 2004.

[59] **F. Melo**, **M. I. Ribeiro**, **P. Lima**, "Navigation Controllability of a Mobile Robot Population", *Proc. of RoboCup 2004 Symposium,* Lisbon, Portugal, July 2004.

[60] **B. Van der Vecht**, **P. Lima**, "Formulation and Implementation of Relational Behaviours for Multi-Robot Cooperative Systems", *Proc. of RoboCup 2004 Symposium*, Lisbon, Portugal, July 2004.

[61] **Vasco Pires**, **Miguel Arroz**, **Luis Custódio**, "Logic Based Hybrid Decision System for a Multi-robot Team", *Proc. 8th Conference on Intelligent Autonomous Systems*, Amsterdam, The Netherlands, March 2004.

[62] **Rui Carvalho, Luis Custódio**, "A Multiagent Systems Approach for Managing Supply-Chain Problems", IBERAGENTS 2004 – Fifth Iberoamerican Workshop on Multi-Agent Systems, *9th Ibero-American Conference on Artificial Intelligence* (IBERAMIA 2004), Mexico, November 2004.

[63] **Muriel Pádua**, **Luis Custódio**, "Search Models and Ill-Structured Problems: a Case-Study on the HIV Vaccine", International J. A. Schumpeter Society, 1*0th ISS Conference - Schumpeter2004, Innovation, Industrial Dynamics and Structural Transformation: Schumpeterian Legacies*, Milan, June 2004.

[64] **Rodrigo Ventura**, **Carlos Pinto-Ferreira**, "Generating and Refining Causal Models for an Emotion-based Agent", in *Architectures for Modeling Emotion: Cross-Disciplinary Foundations, 2004 AAAI Spring Symposium*, AAAI, 2004.

[65] **Jorge Pais, Carlos Pinto-Ferreira,** "Learning Strategies for Qualitative Spatial Reasoning based on Semantics extracted from Human Solutions - A First Attempt", in *ECAI2004 - European Conference for Artificial Intelligence 2004, Workshop of Spatial and Temporal Reasoning*, Valencia, Spain, 2004.

[66] **N. Gracias, J. Costeira, J. Santos-Victor**, "Linear Global Mosaics for Underwater Surveying", *IAV2004* - 5th *IFAC/EURON Symposium on Intelligent Autonomous Vehicles* , Lisbon, Portugal, July 2004.

[67] **R. Vassallo, J. Santos-Victor, H.J. Schneebeli**, "Visuomotor Maps for Robot Task Learning through Imitation", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles* , Lisbon, Portugal, July 2004.

[68] **R. Freitas, J. Santos-Victor, M. Sarcinelli-Filho, T. Bastos-Filho**, "Learning Navigation Maps by Looking at People", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles*, Lisbon, Portugal, July 2004.

[69] **L. GerstMeyer, A. Bernardino, J. Santos-Victor**, "Appearance based landmark selection and Reliability Evaluation for Topological Navigation", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles* , Lisbon, Portugal, July 2004.

[70] **J. Melo, A. Naftel, A. Bernardino, J. Santos-Victor**, "Retrieval of Vehicle Trajectories and estimation of Lane Geometry using non-Stationary Traffic Surveillance Cameras", *ACVIS 2004 - Advanced Concepts for Intelligent Vision Systems*, Brussels, Belgium, Aug. 31-Sept. 3 2004.

[71] **Andrew Naftel, José Melo, Alexandre Bernardino and José Santos-Victor**, "Highway Lane Detection and Classification Using Vehicle Motion Trajectories", *VIIP 2004 - The 4th IASTED International Conference on Visualization, Imaging, and Image Processing*, Marbella, Spain, September 2004.

[72] **J. Melo, A. Naftel, A. Bernardino, J. Santos-Victor**, "Viewpoint Independent Detection of Vehicle Trajectories and Lane Geometry from Uncalibrated Traffic Surveillance Cameras", *ICIAR - International Conference on Image Analysis and Recognition*, Porto, Portugal, Sep.29 - Oct.1 2004.

[73] **V.J.Traver, A.Bernardino, P. Moreno, J. Santos-Victor**, "Appearance-based object detection in space-variant images: a multi-model approach", *ICIAR - International Conference on Image Analysis and Recognition*, Porto, Portugal, Sep.29 - Oct.1 2004.

[74] **M. Lopes, R. Beira, M. Praça, J. Santos-Victor**, "An anthropomorphic robot torso for imitation: design and experiments", *IROS2004 – Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems*, Sendai, Japan, September 28 - October 2 2004.

[75] **João Sequeira, M. Isabel Ribeiro**, "Hybrid control of semi-autonomous robots", IROS2004 – *Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems*, , Sendai, Japan, pp.1838-1844, September 2004.

[76] **João Sequeira, M. Isabel Ribeiro**, "Behavioral control of robot teams", Proc. of the Workshop on Networked Robotics: Issues, Architectures and Applications, part of the *IEEE/RSJ International Conference on Intelligent Robots and Systems*, IROS2004, Sendai, Japan, pp.105-110, September de 2004.

[77] **João Sequeira, M. Isabel Ribeiro**, "Behavior-based control for semi-autonomous robots", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles*, Lisbon, Portugal, July 2004.

[78] **N. F. Gonçalves, P. M. Silva, J. Sequeira, M. I. Ribeiro**, "Modelling and control of a biped Robot", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles*, Lisbon, Portugal, July 2004.

[79] **Alberto Vale, José Miguel Lucas, M. Isabel Ribeiro**, "Feature Extraction and Selection for Mobile Robot Navigation in Unstructured Environments", *IAV2004 - 5th IFAC/EURON Symposium on Intelligent Autonomous Vehicles*, , Lisbon, Portugal, July 2004.

[80] **João Sequeira, M. Isabel Ribeiro**, "Hybrid control of a car-like robot", *Proc. 4th International Workshop on Robot Motion and Control*, RoMoCo'04, Puszczykowo, Polónia, pp. 167-173m, 17-20 June de 2004.

[81] **Francisco Melo, Pedro Lima, M. Isabel Ribeiro**, "Event-Driven Modeling and Control of a Mobile Robot Population", *Proc. da 8th Conference on Intelligent Autonomous Systems* - IAS8, Amsterdão, Holanda, pp.237-244, March 2004.

[82] **José Rocha, João Sequeira**, "The Development of a Robotic System for Maintenance and Inspection of Power Lines", *Proc. of the 35th Int. Symposium on Robotics*, ISR2004, Paris-Nord Villepinte, France, March 23-26, 2004.

[83] **José Rocha, João Sequeira**, "New Approaches for Surveillance Tasks", *IAV 2004 - 5th IFAC/EURON Symposium on Intelligent Vehicles*, Lisbon, Portugal, July 4-7, 2004.

[84] **Bruno B. Gonçalves and Pedro M. Q. Aguiar**, "Complete 3-D models from video: a global approach", *IEEE International Conference on Image Processing*, ICIP'04, Singapore, October 2004.

[85] **Bernardo Esteves Pires and Pedro M. Q. Aguiar**, "Registration of images with small overlap", *IEEE International Workshop on Multimedia Signal Processing* MMSP'04, Siena, Italy, September 2004.

[86] **Pedro M. Jorge, Arnaldo J. Abrantes, Jorge S. Marques**, "Estimation of the Bayesian Network Architecture for Object Tracking in Video Sequences", *International Conference on Pattern Recognition*, vol. 2, 732-735, August 2004.

[87] **Arnaldo J. Abrantes, Jorge S. Marques**, "The Mean Shift and the Unified Framework", *International Conference on Pattern Recognition*, Vol. 1, 244-247, August 2004.

[88] **João M. Sanches and Jorge S. Marques**, "MAP signal reconstruction with non regular grids", *International Conference on Image Analysis and Recognition*, LNCS, vol. 3211, 204-211, 2004.

[89] **Jorge G. Silva, Jorge S. Marques, J. M. Lemos**, "Trajectory Tracking in Manifolds with Tangent Bundle Approximation", *6th IFAC Symposium on Nonlinear Control Systems*, Stuttgart, September 2004.

[90] **Pedro M. Jorge, Arnaldo J. Abrantes, Jorge S. Marques**, "On-line Tracking Groups of Pedestrians with Bayesian Networks", *Workshop PETS, 65-72*, Prage, May 2004.

[91] **Pedro M. Jorge, Arnaldo J. Abrantes, Jorge S. Marques**, "On-line Object Tracking with Bayesian Networks", *International Workshop on Image Analysis for Multimedia Interactive Systems*, Lisbon, April 2004.

[92] **R. J. Oliveira P. C. Ribeiro J. S. Marques J. M. Lemos**, "A Video System for Urban Surveillance: Function Integration and Evaluation", *International Workshop on Image Analysis for Multimedia Interactive Systems*, Lisbon, April 2004.

[93] **J. Nascimento, Jorge S. Marques**, "New Performance Evaluation Metrics for Object Detection Algorithms", *Workshop PETS,* Prage, May 2004.

[94] **J. Xavier and V. Barroso**, "The Riemannian Geometry of Certain Parameter Estimation Problems with Singular Fisher Information Matrices", *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'04)*, vol. 2, pp. 1021-1024, Montreal, Canada, 2004.

[95] **J. Xavier and V. Barroso**, "Geodesic Lower Bound for Parametric Estimation with Constraints", *Proc. Workshop on IEEE Signal Processing Advances on Wireless Communications (SPAWC'04)*, Lisbon, Portugal, July 2004.

[96] **J. Gomes, V. Barroso**, "MIMO Decision-Feedback Equalization with Direct Channel Estimation", *Proc. 5th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC'04),* Lisbon, Portugal, July 2004.

[97] **J. Gomes, V. Barroso**, "Time-Reversed OFDM Communication in Underwater Channels", *Proc. 5th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC'04),* Lisbon, Portugal, July 2004.

[98] **J. P. Caldeira, F. Melício, A. C. Rosa**, "Using a Hybrid Evolutionary-Taboo Algorithm to solve the JobShop Problem", *Proc. ACM SAC 2004*, Nicosia, Cyprus, March 2004.

[99] **Conceição C., Costa J., Rosa A. C.**, "Drowsiness Detection on Electroencephalogram Using Evolutionary Algorithms", *Proc. IASTED ICBE – BioMed 2004*, Austria, 2004.

[100] **Melicio F. M., Caldeira J. P., Rosa A. C.**, "Two neighbourhood approaches to the timetabling problem" – *Proc. PATAT 2004*, LNCS, 2004.

[101] **Jesus S. M., Soares C., Silva A. J. and E. Coelho,** "Acoustic Oceanographic Buoy testing during the Maritime Rapid Environmental Assessment 2003 sea trial", *Proc. ECUA'04 - 7th European Conference on Underwater Acoustics*, Delft, The Netherlands, July 2004.

[102] **Soares C., Jesus S. M. and E. Coelho, "**Shallow water tomography in a highly variable scenario", *Proc. Acoustics Inversion Methods and Experiments for Assessment of the Shallow Water Environment*, Ischia, Italy, June 2004.

[103] **Jesus S. M. and Silva A. J.,** "Time reversal and spatial diversity: issues in a time varying geometry test", *Proc. of Conference on High Frequency Ocean Acoustics*, San Diego, USA, March 2004.

[104] **Rodriguez O. C. and Jesus S. M.,** "Range dependent tomography of internal tides with relative arrivals", *Proc. International Conference on Computational and Experimental Eng. Sciences*, Madeira, Portugal, July 2004.

[105] **Jesus S. M., Soares C. and Martins N.,** "Acoustic Rapid Environmental Assessment: the AOB concept", *Maritime Rapid Environmental Assessment Workshop*, NURC, La Spezia, Italy, December 2004.

[106] **Jesus S., Soares C., Silva A., Hermand J.-P. and Coelho E. F.,** "AOB - an easily deployable, reconfigurable and multifunctional acoustic-oceanographic system", *148th Meeting of the Acoustical Society of America*, San Diego, USA, November 2004.

[107] **Loke, R.E. and du Buf, J.M.H.**, "Small CPU times and fast interactivity in sonar seabottom surveys", *Proc. 2nd International Symposium on 3D Data Processing, Visualization, and Transmission*, 3DPVT, Thessaloniki, Greece, Sept. 6-9 2004.

[108] **P.-M. Sarradin, J. Sarrazin, J. F. Cadiou, K. Olu, D. Desbruyeres, V. Rigaud, J. F. Drogou, F. Lecornu, J. F. Rolin, R. Vuillemin, M. A. Cambon-Bonavita, E. Sauter, K. von Juterzenka, A. Boetius, R. Serrao Santos,**

**A. Colaco, A. Pascoal, P. Oliveira, B. Shillito, F. Zal, A. Schultz, P. Taylor, D. Lane, R. E. Loke, H. du Buf, C. Waldmann, A. Cormack, L. Sanfilippo, M. Masson**, "Extreme ecosystem studies in the deep ocean: Technological Developments", *Proc. 14th International Offshore and Polar Engineering Conference*, Toulon, France, Vol I, pp 738-746, ISBN 1-880653-62-1, May 23-28 2004.

[109] **P.-M. Sarradin, J. Sarrazin, K. Olu, E. Sauter, R. Serrao Santos, A. Pascoal, B. Shillito, F. Zal, A. Schultz, D. Lane, H. du Buf, C. Waldmann, A. Cormack, L. Sanfilippo, M. Masson**, "Extreme ecosystem studies in the deep ocean: technological developments", *Eurocean 2004*, Galway, Ireland, May 10-13, 2004.

[110] **Rodrigues, J. and du Buf, J. M. H.**, "A vision frontend with a new disparity model", *Early Cognitive Vision Workshop* (ECOVISION), Isle of Skye, Scotland, May 28 - June 1 2004.

## G) IN NATIONAL CONFERENCES (6):

[111] **Rui Carvalho, Luis Custódio**, "Concepção de um Sistema Multi-Agente para a Resolução de Problemas de Cadeias de Produção-Distribuição'', *5ª Conferência da Associação Portuguesa de Sistemas de Informação* (CAPSI), Lisbon, November 2004.

[112] **V. Pires, M. Arroz, L. Custódio, P. Lima, M. I.Ribeiro**, "Distributed Deliberative Decision System for a Multi-Robot", *Proc. Encontro Científico do 4º Festival Nacional de Robótica*, ROBOTICA2004, Porto, pp.127-134, April 2004.

[113] **Carlos Alfaro, M. Isabel Ribeiro, Pedro Lima**, "Smooth Local Path Planning for a Mobile Manipulator", *Proc. Encontro Científico do 4º Festival Nacional de Robótica*, ROBOTICA2004, Porto, pp.17-24, April de 2004.

[114] **Felisberto P. and Jesus S.M.,** "Mapeamento espacial de perturbações da temperatura do oceano por integração sistemática de dados acústicos e medições in-situ", *Jornadas do Mar: um Oceano de Oportunidades*, Escola Naval, Lisbon, November 2004.

[115] **Soares C. and Jesus S. M.,** "Processamento por ajuste de campo em acústica submarina e aplicações", *Jornadas do Mar: um Oceano de Oportunidades*, Escola Naval, Lisbon, November 2004.

[116] **Rodrigues, J. and du Buf, J. M. H.**, "Visual cortex frontend: integrating lines, edges, keypoints and disparity", *ICIAR2004 -Proc. International Conference on Image Analysis and Recognition*, Porto, Portugal, Springer LNCS 3211, pp. 664-671, 29 September - October 1 2004.

## H) TECHNICAL REPORTS (30) :

[117] **A. Alcocer, P. Oliveira, A. Pascoal**, "Outlier Detection in an Acoustic-Based Positioning System for Autonomous Underwater Vehicles", DSORL-ISR Technical Report, August 2004.

[118] **João Alves, C. Silvestre**, "Real Time Control Architectures for Autonomous Vehicles", DSORL-ISR Technical Report, October 2004.

[119] **E. Barros, A. Pascoal**, "Estimation of the Hydrodynamic Derivatives of the MAYA-AUV using Analytical and Semi-Empirical Methods", DSORL-ISR Technical Report, August 2004.

[120] **Bruno Cardeira, Carlos Silvestre, Paulo Oliveira**, "High Accuracy Data Acquisition Architectures for Inertial Navigation Systems", DSORL-ISR Technical Report, December 2004.

[121] **D. Carvalho and A. Pascoal**, "Study of a Path Following Systems for a Fully Actuated Underwater Vehicle", Joint DSORL-ISR/UFES Technical Report, December 2004.

[122] **Cybernetix (FR), CEA (FR), DUTH (GR), IFREMER (FR), IST/ISR (PT), JRC (IT), U. Southampton (UK)**, "FREESUB: Autonomous Underwater Vehicle for Subsea Interventions", Final Project Report, October 2004.

[123] **S. Fekriasl**, "Robust Adaptive MIMO Control using Multiple-Model Hypothesis Testing and Mixed Mu-Synthesis", DSORL-ISR Technical Report, October 2004.

[124] **R. Ghabcheloo, A. Pascoal, C. Silvestre**, "Coordinated Path Following Control using Linearization Techniques", DSORL-ISR Technical Report, February 2004.

[125] **R. Ghabcheloo, A. Pascoal, C. Silvestre**, "Coordinated Path Following Control using Nonlinear Techniques", DSORL-ISR Technical Report, November 2004.

[126] **Paulo Oliveira**, "Terrain Based Navigation Tools for Underwater Vehicles using Eigen Analysis", ISR Technical Report, November 2004.

[127] **Paulo Oliveira**, "PCA Positioning Sensor Characterization for Terrain Based Navigation of Uvs", ISR Technical Report, September 2004.

[128] **Nuno Paulino, C. Silvestre, Rita Cunha**, "Preview Controllers for Affine Parameter Dependent Systems: An Application to Rotorcraft Flight Controllers", DSORL-ISR Technical Report, September 2004.

[129] **A. Pascoal, C. Silvestre, P. Oliveira, L. Sebastião**, "The work of IST in the scope of the EXOCET/D project: a Summary", EXOCET/D Report EXOCET.INT01.2004, Instituto Superior Técnico, December 2004.

[130] **L. Sebastião, J. Alves, A. Pascoal, F. Cardigos, A. Colaço**, "Acoustic Data Acquisition for Automatic Benthic Classification (Laboratory Tests)", EXOCET/D Report EXOCET.AC00.2004, Instituto Superior Técnico, October 2004.

[131] **L. Sebastião, A. Pascoal, F. Cardigos, A. Colaço**, "Acoustic Data Acquisition for Automatic Benthic Classification (Field Tests)", EXOCET/D Report EXOCET.AC01.2004, Instituto Superior Técnico, June 2004.

[132] **F. Teixeira**, "AUV Terrain Aided Navigation using Particle Filters", DSORL-ISR Technical Report, December 2004.

[133] **J. Vasconcelos, P. Oliveira, C. Silvestre**, "Inertial Navigation System Aided by GPS and Selective Frequency Contents of Vector Measurements", ISR Technical Report, December 2004.

[134] **João Costal**, "Formações de Robots Aéreos e Terrestres", Final Year and RESCUE Project Technical Report, IST Aerospace Engineering degree, October 2004.

[135] **Pedro Lima, Dan Dumitriu, Sónia Marques**, "Candidate Formation Algorithms Simulation Results and Performance Assessment", TN4-FEMDS-8Nov2004.

[136] **Pedro Lima, Dan Dumitriu, Sónia Marques**, "Candidate Estimation, Guidance and Control Algorithms Functional Design and Analysis", TN3-FEMDS-29Sep2004.

[137] **Francisco Melo, Maria Isabel Ribeiro**, "Blocking Controllability of a Mobile Robot Population", Technical Report, RT-601-04, Instituto de Sistemas e Robótica, pólo do Instituto Superior Técnico, May 2004.

[138] **M. Isabel Ribeiro**, "Kalman and Extended Kalman Filters: Concept, Derivation and Properties", Instituto de Sistemas e Robótica, Instituto Superior Técnico, Fevereiro de 2004. Published at Robotics WEBook, http://www.euron.org.

[139] **M. Isabel Ribeiro**, "Gaussian Probability Density Functions: Properties and Error Characterization", Instituto de Sistemas e Robótica, Instituto Superior Técnico, Fevereiro de 2004. Published at Robotics WEBook, http://www.euron.org.

[140] **A.Bernardino, L.Custódio, J.Frazão, P.Lima, F.Melo, M.I.Ribeiro, J.Santos-Victor, A.Vale**, "RESCUE Project Final Report", November 2004.

[141] **Sérgio Guerreiro, João Sequeira**, "An Information System Architecture for Project POSI/SRi/40999/2001 – SACOR", project report, December 2004.

[142] **João Cristóvão, Carlos Marques, João Frazão, Pedro Lima, M. Isabel Ribeiro**, "RAPOSA Project -Second Milestone Report", March 2004.

[143] **João Cristóvão, Carlos Marques, João Frazão, Pedro Lima, M. Isabel Ribeiro**, "RAPOSA Project -Third and Fourth Milestones Report", October 2004.

[144] **Martins N.,** "Processamento por Adaptação de campo no domínio frequência-Doppler", 02/04-SiPLAB Report, University of Algarve, May 2004.

[145] **Bobinger, U. and du Buf, H.**, "Modeling Visual Detection: MODELFEST data", Report CINTAL/UALG, 6 pp., 2004.

[146] **Bobinger, U. and du Buf, H.**, "Modeling Visual Detection: CIF data", Report CINTAL/UALG, 7 pp., 2004.

## *3.12 SUBMITTED / ACCEPTED PAPERS*

### I) IN BOOKS (4)

[147] **P. Lima, L. Custódio**, "Multi-Robot Systems", *Capítulo I de Machine Learning, Perception and Robot Cognition*, S. Patnaik, S. Tzafestas, Eds., Springer Verlag, Berlin, accepted for publication in 2005.

[148] **P. Lima, L. Custódio**, "RoboCup 2004 Overview", *RoboCup-2004: Robot Soccer World Cup VIII*, D. Nardi, M. Riedmiller, C. Sammutt, J. Santos-Victor, Eds., Springer Verlag, Berlin, accepted for publication in 2005.

[149] **Agostinho Rosa, D. Poyares, C Guilleminault**. "Processamento de sinais eletrofisiológicos para análise e classificação automática do sono". Em *Manual de Poligrafia do Sono,* Edição da Sociedade Brasileira de Sono. To appear in 2005.

[150] **Agostinho Rosa, Maria-Cecilia Lopes**, "Padrão Alternante Cíclico (CAP) ". Em *Manual de Poligrafia do Sono,* Edição da Sociedade Brasileira de Sono. To appear in 2005.

### J) INTERNATIONAL JOURNALS (14)

[151] **R. Ghabcheloo, A. Pascoal, C. Silvestre** , **I. Kaminer**, "Coordinated Path Following Control of Multiple Wheeled Robots using Linearization Techniques". Accepted for publication. To appear in the *International Journal of Systems Science*, 2005.

[152] **P. Tabuada, G. Pappas and P. Lima**, "Motion Feasibility of Multi-Agent Formations", *IEEE Transactions on Robotics* (accepted for publication in 2005).

[153] **P. Lima, L. Custódio, Akin l., Jacoff A., Kraezschmar G., Kiat Ng B., Obst O., Röfer T., Takahashi Y., Zhou C.**, (2005), "RoboCup 2004 Competitions and Symposium: A Small Kick for Robots, a Giant Score for Science", *AI-Magazine*, (invited and accepted for publication in 2005).

[154] **D. Milutinovic**, **J. Carneiro, M. Athans, P. Lima**, "Modeling the Hybrid Dynamics of TCR Signaling in Immunological Synapses", *Journal of Theoretical Biology* (under revision).

[155] **D. Milutinovic**, **P. Lima**, "Modeling and Control of a Large-Size Robotic Population", *IEEE Transactions on Robotics* (under revision).

[156] **João Sequeira, M. Isabel Ribeiro**, "A Semiotic Approach to the Control of Semi-Autonomous Robots", *International Journal of Systems Science*, special issue in Cooperative Control Approaches for Multiple Mobile Robots ,Taylor & Francis (accepted for publication).

[157] **João Sequeira, M. Isabel Ribeiro**, "Robot Team Control: a Geometric Approach", *Journal of Robotics and Autonomous Systems* (accepted for publication).

[158] **Martins N., Jesus S. M.,** "Blind estimation of the ocean acoustic channel by time-frequency processing", *IEEE Journal of Oceanic Engineering* (accepted for publication).

[159] **Loke, R.E. and du Buf, J.M.H.**, "3D data segmentation by means of adaptive boundary refinement in an octree", *Journal of Pattern Recognition* (2nd version).

[160] **Loke, R. E. and du Buf, J. M. H.**, "Linking matched cubes: efficient triangulation of 18-connected object boundaries", Submitted to: *The Visible Computer* (2nd version), 2004.

[161] **Pedro M. Q. Aguiar and José M. F. Moura**, "Figure-Ground Segmentation from Occlusion", *IEEE Transactions on Image Processing* (accepted for publication).

[162] **Maria Cecília Lopes, Agostinho Rosa, Dalva Poyares, Suely Roizenblatt, Cassia Passarelli, Sergio Tufik**, "Cyclic Alternating Pattern in peripubertal Children", *Sleep*, February 2005 issue.

[163] **André T. Martins, Pedro M. Q. Aguiar, and Mário A. T. Figueiredo**, "Orientation in Manhattan: Equiprojective Classes and Sequential Estimetion", IEEE Transactions on Pattern Analysis and Machine Intelligence, 2004 (accepted for publication).

[164] **M. Cabido Lopes, J. Santos-Victor**, "Visual learning by imitation with motor representations", *IEEE Transactions on Systems, Man and Cybernetics*, special issue on Learning in Computer Vision and Pattern Recognition (accepted for publication).

## K) INTERNATIONAL CONFERENCES (1)

[165] **D. Dumitriu**, **B. Udrea, P. Lima**, "Optimal Trajectory Planning Of Formation Flying Spacecraft", *Proc. of IFAC World Congress 2005*, Prague, Czech Republic (accepted for publication).

## *4.0 LABORATORY FACILITIES AND SERVICES*

## *4.1 COMMON FACILITIES*

ISR/IST has a computer network infra-structure based on 2 DEC Alpha servers and 7 DEC Alpha workstations. The Computing Center group runs also three Macintosh computers and 4 laser printers. More than 200 users have accounts on the isr.ist.utl.pt domain, and more than 100 machines, including PCs, SUN workstations, Macintoshes and others, are currently linked to the network.

## *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);
- 1 (soon 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:**

- 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);
- 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*);
- 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 Control 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;
- 2 Sick Laser Scanners;
- Three computers 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;
- A large open space appropriate for mobile robotics navigation experiments.

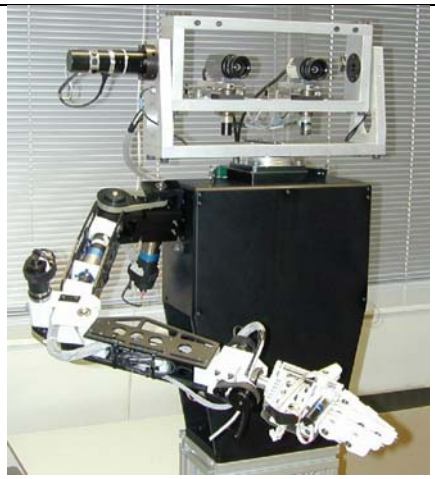
## *COMPUTER VISION Lab (VISLAB)*

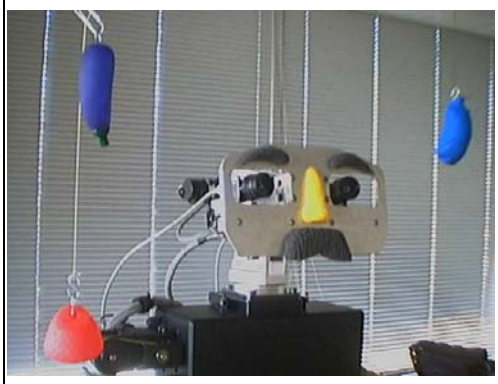
The VisLab is equipped with various PCs, various cameras (CCD, CMOS, Colour, Black & White, Digital or Analogue) and image frame grabbers, a pan-tilt unit and several pan-tilt cameras.

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 PROCESSING Lab (SP) - 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.

- 8 Intel-compatible personal computers;
- 1 Hewlett-Packard LaserJet 4M printer;
- 100 Mbit/s thin Ethernet LAN interfacing the Signal Processing Laboratory to the ISR Network;
- 1 ORCA underwater acoustic communication system (surface modem with programmable acoustic receiver, underwater modem);
- 2 Texas Instruments TMS320C6711 hardware/software DSP development systems;
- 1 Analog Devices SHARC ADSP21061 hardware/software DSP development systems;
- 1 Motorola DSP96002 hardware/software DSP development system;
- 1 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;
- 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 PROCESSING Lab (SP) – 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;
- 1 260-900 Hz high power acoustic sound source (tomography).

## *DYNAMICAL SYSTEMS AND OCEAN ROBOTICS LAB (DSOR)*

**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;

- **Mechanical / Electric shop** (8th Floor of ISR) - basic equipment and tools to machine mechanical pieces and to assemble circuit boards;
- **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.**

a. 11 Desktop PCs;
b. 7 Laptop PCs;
c. 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;