INSTITUTO DE SISTEMAS E ROBÓTICA

Pólo de Lisboa – Instituto Superior Técnico

RELATÓRIO DE ACTIVIDADES 2010

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OVERVIEW

This report starts with the description of the current scientific interests of the different groups/labs of ISR/IST, followed by the presentation of the research activities.

During 2010, research activities at ISR/IST were developed essentially in the framework of 42 research projects, 30 under national funding, and 12 under international funding awarded by the EU. The Foundation for Science and Technology (FCT) is the principal source of national funding with 25 research projects. After the description of these projects, the activities reports of the 7 Post-Docs working at ISR/IST are presented.

Eight (8) PhD theses and nineteen (19) MSc theses were successfully concluded during 2010. More sixty eigth (68) PhD and nineteen (19) MSc students are being supervised by senior researchers of ISR/IST. Besides this, ISR/IST was also intensively involved in the offer and teaching of courses in doctoral programs, and in the organization of regular internal seminars, some of them given by researchers coming from international institutions.

Our researchers were invited to give talks in other universities and research institutions, twenty eigth (28) of them abroad. They participated in a great number of international congresses and meetings. They served as associate or guest editors in four (4) archive scientific journals, and as members of the advisory boards of eleven (11) international organizations. We contributed with more than fourty nine (49) members of technical and programme committees of diversity of international conferences and with regular reviewing activities in more than fifty two (52) international journals.

We received the visit of ten (10) distinguished visitors coming from international universities and research institutions in the whole world.

The results of the research conducted at ISR/IST was published as seven (7) contributions to book chapters, thirty (30) papers in international archive journals, one hundred and fourty eight (148) communications in proceedings of international conferences. There are also four (4) articles published in national journals and twelve (12) communications in national conferences.

1 RESEARCH TEAM AND INTERESTS

1.1 MEMBERS AND COLLABORATORS

THEORY GROUP

Michael ATHANS, *Principal Researcher*

INTELLIGENT ROBOTS AND SYSTEMS GROUP

Isabel RIBEIRO, *Full Professor (IST)*
Pedro LIMA, *Associate Professor (IST)*
Carlos BISPO, *Assistant Professor (IST)*
João SEQUEIRA, *Assistant Professor (IST)*
Rodrigo VENTURA, *Assistant Professor (IST)*
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Bruno LACERDA, *Ph.D. St., FCT grantee*
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COMPUTER AND ROBOT VISION

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Andre ROSADO, *M.Sc. - Researcher*
Joao PM RODRIGUES, *M.Sc. – Researcher*
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Luis RAMALHO, *M.Sc. St.*
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1.2 CURRENT RESEACH INTERESTS

The Lisbon pole of ISR is internally organized in 5 laboratories/groups. In this section the main research interests of each one of the laboratories/groups are briefly described.

1.2.1 Intelligent Robots and Systems Group

The driving theme of the Intelligent Robots and Systems Group is wide in scope. Its members approach complex systems from a holistic standpoint, rather than focusing on some of the subsystems. The topic of cooperation (among agents and/or robots, among robots and humans) arises naturally from this viewpoint. The historic background of the lab senior researchers has lead us to use Artificial Intelligence concepts (e.g., sequential decision making, learning, task planning, cognitive systems) driven by formal approaches that stem from Systems and Control Theory and from Operations Research (e.g., mathematical modeling, analysis and synthesis, optimization, path planning, navigation, localization, discrete-event systems, estimation theory, simulation, queuing theory, Markov systems). Our research is often driven by practical applications, as we strongly believe it is very important to apply our methodologies to practical domains, as challenging real-life problems provide richer sources of inspiration. Therefore, we have been exploring the application of our research on (cooperative) navigation, sensor fusion, planning under uncertainty, dynamic modeling, non-smooth systems, human-robot interaction, discrete event systems, bio-inspired approaches, cognitive architectures, to networked robot systems, remote handling systems, kinematically complex robots, field robots and soccer robots, humanoid robots, scheduling of queuing networks, and management of health systems, to name but a few.

Our distinctive feature is that we bring together people with a common background on systems theory, but different approaches to modeling, analysis and synthesis of intelligent systems, mainly coming from:

- artificial intelligence, with a focus on decentralized and distributed methods, and specific interest in planning under uncertainty, organizational issues, neurosciences-, biology- and social sciences-inspired robot architectures and methods;
- systems and control, with a focus on complex systems consisting of a large number of interconnected embedded systems, e.g., sensor and robot networks, institutional management systems, biological systems, navigation of autonomous systems and specific interest on modeling, analysis and synthesis methods.

In the following, we provide some details on the research and development topics covered by the Lab members in 2010, as well as on the major results achieved.

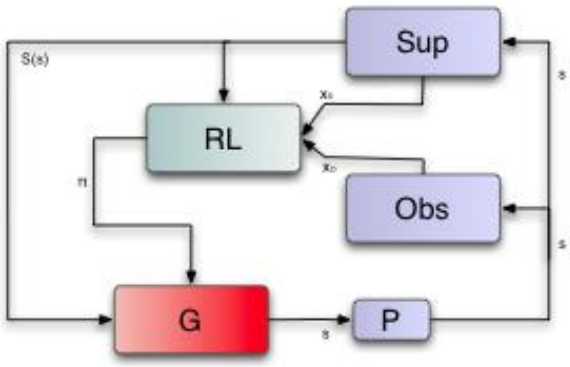
Discrete Event System Models of Robotic Plans

Thesis: 3 PhD (Hugo Costelha - finished, Gonçalo Neto - finished, Bruno Lacerda - ongoing), 3MSc (Manuel Biscaia, Carlos Martins, Nuno Rodrigues –allfinished)

Projects: 1 ISR Project (SocRob)

Most of the existing robotic task models are not based on formal approaches, are concerned only with a small number of behaviors and are typically tailored to the task at hand. We have proposed, back to 1998, a systems-theory-based task modeling approach for general robotic tasks which enables a systematic approach to modeling, analysis and design, scaling up to realistic applications, providing methods for logical verification, stochastic performance, and design from specifications, as well as execution improvement over time through learning. Our approach is based on using discrete event systems (DES) models, mainly Petri nets and finite state automata, for robot plans representation. This particular representation enables using all the available DES analysis and design tools to handle robotic task formal analysis and design.

Several lines of research were pursued under this topic:



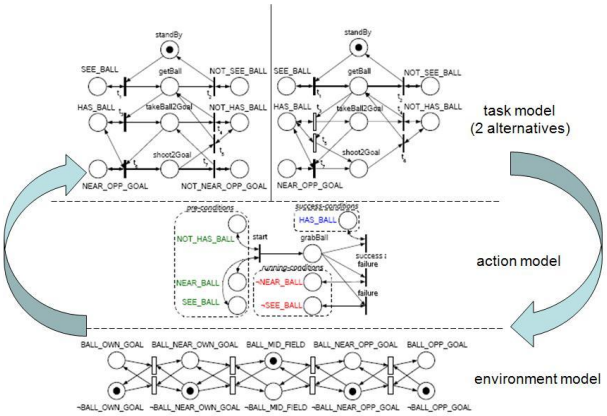
Hybrid Approach to Robot Task Planning, Learning and Control Under Uncertainty: we developed a hybrid approach to robot task planning, learning and control under uncertainty that combines supervisory control of DES and Reinforcement Learning (RL). We assume the system to be modeled by a DES model and build a supervisor, which restricts the original robot behaviors (expressed as the marked language of the DES model) to a subset, based on design specifications. RL is used to determine the optimal robot behavior (plan), within the subset of behaviors allowed by the supervisor, iteratively, online and along the robot course of action. Our approach reduces the size of the RL problem and speeds up the convergence to the optimal controller policy. We consider continuous time since, by definition, the state changes in a DES are event-driven and do not necessarily occur at constant time intervals. For that reason, our RL algorithm is an extended version of Q-learning that converges for continuous-time environments and semi-Markov processes. Some events are unobservable by the supervisor and controller. We address this problem by building an environment observer that supports the decision-making process.

Robotic task supervision using LTL: Supervisory Control of DES consists of restricting the behavior of a DES in order to achieve a set of specifications, usually expressed as required and/or admissible languages, with respect to the original language of the unsupervised system. In this work, we use Linear-Time Temporal Logic (LTL), an extension of Propositional Logic, which allows reasoning over an infinite sequence of states, to specify the performance objectives for a given DES in a more natural language, and build a supervisor that restricts the DES' behavior to those objectives by construction.

Cooperative plan representation and execution: For Petri net (PN) models of the environment, where transitions are associated to robot controllable events (thus representing its effects), or uncontrollable events (thus representing environment natural events, including those caused by other agents starting their own actions), the key issue is that one can build a large complex robotic task model by connecting simple PN modules which represent the dynamic of the robot subsystems (e.g., the PN representing the navigation system, or the perception system status). Macro-actions can also encapsulate action compositions. Petri net plan representations are especially adequate to represent plans for cooperative robots. In this case, places must also represent communicated messages (sent and received), which in fact represent again predicates which, when their arguments are instantiated, become true or false propositions. Examples: *waiting4you_sent, waiting4you_received, arriving_sent, arriving_received*. Two types of communicated signals are relevant for cooperation (coordination + teamwork): those required for synchronization, and those

required for commitment. Synchronization concerns coordination, e.g., two robots transporting a bar and exchanging signals to avoid that one of them advances too much ahead or lags behind.

We have been using PNs to program individual and relational behaviors in the SocRob project with soccer robots, with synchronization and commitment. Commitment is based on the formalism of Cohen's and Levesque's joint intentions theory, and essentially assures teamwork, i.e., once two or more robots get involved in a relational behavior, they mutually commit to inform their involved teammates if the joint goal became irrelevant or can not be reached anymore (e.g., due to a failure of one of them to proceed with its part of the behavior).



Robotic task performance analysis using Petri nets: The whole robot plan, represented by a PN, can be composed with the environment pan, also represented by a PN. Robotic task performance analysis should be performed over the above closed loop model of the robot situated in its environment. Two main classes of analysis problems are: i) qualitative/logical analysis: such as determining PN liveness (is the plan resettable, can the robot recover from an error?), boundedness (are we using too many resources, e.g., calling a primitive action to run concurrently in a number of processors - or robots - larger than those available?), blocking (deadlocks, livelocks); ii) quantitative/stochastic performance analysis: is a plan robust to changes of primitive action reliability around their nominal values? What is the probability of success of a plan, given the reliability of its composing primitive actions?

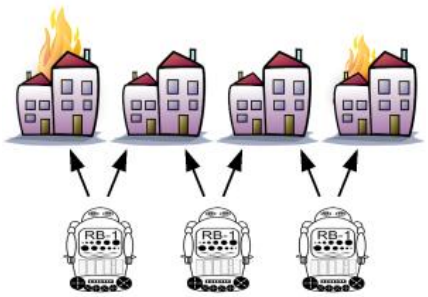
Main achievements in 2010

We formalized the representation of single and multi-robot plans by Petri nets, and used those models to design plans for real robots applied to the soccer domain. The model is based on a closed-loop between the Petri net plan and a Petri net model of the environment surrounding the robot(s), and its stochastic Petri net view enables studying quantitative properties of the system model in closed form, solving Markov chains. The parameters of the environment model Petri net are identified by an estimation algorithm.

We have also developed a hybrid approach to robot task planning, learning and control under uncertainty that combines supervisory control of DES and Reinforcement Learning (RL).System models and supervisors are represented by finite state automata. RL is used to determine the optimal robot behavior (plan), within the subset of behaviors allowed by the supervisor, iteratively, online and along the robot course of action. Our approach reduces the size of the RL problem and speeds up the convergence to the optimal controller policy. Some events are unobservable by the supervisor and controller. We address this problem by building an environment observer that supports the decision-making process.

(Decentralized) Planning Under Uncertainty

Thesis: 2 PhD (JoãoMessias, Tiago Veiga – both ongoing), 2 MSc (Ana Rita Mendes, Tiago Veiga – both concluded)



Projects: 1 FCT project (Dec-PUCS), 1 CMU-Portugal Project (MAIS-S)

This research concerns computing plans for single agents as well as cooperative multiagent systems, in domains in which an agent is uncertain about the exact consequences of its actions. Furthermore, it is equipped with imperfect sensors, resulting in noisy sensor readings which provide only limited information. For single agents, such planning problems are naturally framed in the partially observable Markov decision process (POMDP) paradigm. In a POMDP, uncertainty in acting and sensing is captured in probabilistic models, and allows an agent to plan on its belief state, which summarizes all the information the agent has received regarding its environment. For the multi-agent case, we frame our planning problem in the decentralized POMDP (Dec-POMDP) framework. Recent research has been focusing on developing theory, as well as applying such methodologies to sensor and mobile robot networks.

Optimal Dec-POMDP solving:
Last year, we proposed a fast algorithm for optimally solving the one-step backup in Dec-POMDPs, and we have been building on this work to significantly improve the scalability of optimal Dec-POMDP solvers, which need to reason about multiple time steps. So far, this has allowed us to increase the planning horizon for optimally solving several benchmark problems with multiple time steps, which is no trivial feat due to the doubly-exponential nature of solving Dec-POMDPs optimally.

Reinforcement learning for multiagent POMDPs:
With Rajneesh Sharma we have been developing reinforcement-learning methods for multiagent and decentralized POMDPs, an area in which relatively little work has been published. We combine our existing framework of modeling Dec-POMDPs as series of Bayesian games with fuzzy inference systems as function approximators.

POMDP Task auctions:
We presented a method for using auction protocols to achieve multi-robot coordination on a task level, by modeling each individual task as a POMDP. This is a way of using communication for multiagent planning under uncertainty without relying on high-bandwidth high-reliability communication. This is crucial when dealing with robotic systems. In collaboration with the University of Seville, we extended this model to fully decentralized settings by adding a decentralized state filter, and apply it in real multi-robot experiments.

Multiagent planning under uncertainty for multi-robot systems:
With João Messias we have been working on developing methods for multiagent planning under uncertainty for multi-robot systems. Such real-world systems violate several assumptions typically made in the field. For instance, synchronization issues between agents are not considered or when communication is available it is assumed to be flawless and instantaneous. The work focuses on planning with uncertain communication, by developing robustplan representations that can incorporate communication when available, but do not depend on it (which leads to brittle systems).

Planning under uncertainty for Search and Rescue:
Ana Rita Mendes wrote an MSc thesis on the application of POMDPs in a realistic search and rescue situation. Specifically, the aim of the problem is to find victims in a disaster environment. The thesis and paper define, implement and test a POMDP model that suits the problem and its characteristics. The environment and its features is learned (by letting the robot interact with it) and taken into account when building the model. It can be concluded that POMDP-based solutions, and this solution in particular, can work well in these search and rescue scenarios.

Main achievements in 2010

We made significant progress in scaling up multiagent planning under uncertainty techniques, by speeding up the one-step decision problem in Dec-POMDPs with up to 10 orders of magnitude on some benchmark problems (AAMAS2010). Furthermore, a key strength of the ISR research working on these topics is the focus on techniques that are applicable in real-world systems such as multi-robot systems. For instance, we explicitly take into account the limitations of intra-robot communication (ICRA 2010), designing techniques that allow robots to exploit communication when available, but not critically depend on it. Another key aspect of multi-robot systems is that they are embedded in physical environment, which means their interactions are often local only, which we take advantage of when planning their joint task.

Cooperative Perception

Thesis: 2 PhD (Aamir Ahmad, AbdolkarimPahliani – both ongoing)

Projects: 2 FCT (Dec-PUCS, PCMMC)

Cooperative perception refers to the fusion of sensory information between fixed surveillance cameras and robots, with as goal maximizing the amount and quality of perceptual information available to the system. This concepts extends that of sensor fusion, as (dis)agreements between sensors, and share of estimates among teammates (e.g., ensuring that a robot that does not perceive an object can know its location) are included.

This information can be used by a robot to choose its actions, as well as to provide a global picture for monitoring the system. In general, incorporating information from spatially distributed sensors will raise the level of situational awareness. Active perception means that an agent considers the effects of its actions on its sensors, and in particular it tries to improve their performance. This can mean selecting sensory actions, for instance pointing a pan-and-tilt camera or choosing to execute an expensive vision algorithm; or to influence a robot's path planning, e.g., given two routes to get to a desired location, take the more informative one. Performance can be measured by trading off the costs of executing actions with how much we improve the quality of the information available to the system, and should be derived from the system's task. Combining the two concepts, cooperative active perception is the problem of active perception involving multiple sensors and multiple cooperating decision makers.

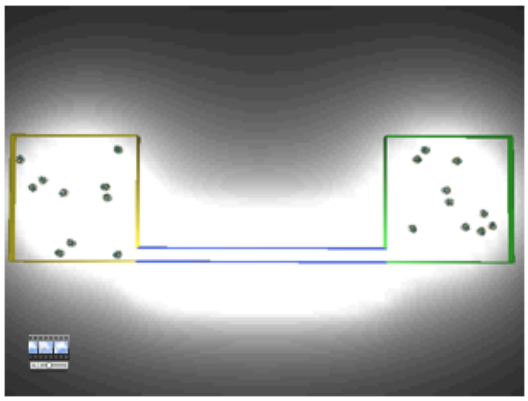
In general, we consider decision-theoretic approaches to cooperative active perception. We propose to use Partially Observable Markov Decision Processes (POMDPs) as a framework for active cooperative perception. POMDPs provide an elegant way to model the interaction of an active sensor with its environment. Based on prior knowledge of the sensor's model and the environment dynamics, we can compute policies that tell the active sensor how to act, based on the observations it receives. As we are essentially dealing with multiple decision makers, it could also be beneficial to consider modeling (a subset of) sensors as a decentralized POMDP (Dec-POMDP). In a cooperative perception framework, an important task encoded by the (Dec-)POMDP could be to reduce the uncertainty in its view of the environment as much as possible. Entropy can be used as a suitable measure for uncertainty. However, using a POMDP solution, we can tackle more elaborate scenarios, e.g., in which we prioritize the tracking of certain objects. In particular, POMDPs inherently trade off task completion and information gathering.

Main achievements in 2010

In this period we divised an algorithm that handles Cooperative Perception problems under a common Bayesian framework, based on particle filters, for moving targets and observer sensors. We have also

published work on cooperatively improving the localization of robots in a team by using information on the position of an object visually shared by the robots

Institutional Robotics



1 PostDoc involved (Porfírio Silva)

Thesis: 1 PhD (José N. Pereira - ongoing)

Projects: 1 FCT (BioInstBots)

Distinct lines of research have been pursued under this topic.

Institutional Robotics is a new strategy to conceptualize multi-robot systems, which takes institutions as the main tool of social life of robots with bounded rationality and bounded autonomy. This institutional approach intends to get inspiration from philosophical and social sciences research on social and collective phenomena, and is mainly inspired by concepts from Institutional Economics, an alternative to mainstream neoclassical economic theory. The goal is to have multiple robots developing activities in a shared environment with human, in such a way that humans can interact with robots "naturally", intuitively, without a need to learn specific techniques to deal with them. The focus is not one-to-one interaction, but social behavior in physical and social environments populated with many natural as well as artificial agents. So, the robots must be able to recognize institutions and institutional indicators that humans also recognize as structuring forms of their complex social relationships. This includes, for instance, rules, routines, signs, forms of organization of the material world, social roles, and social forms as organizations or teams.

Main achievements in 2010

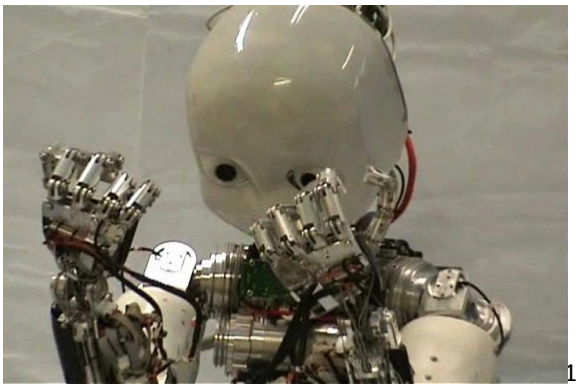
In this period, a paper comparing how Institutional Robotics principles and Swarm Robotics principles handle a problem of transportation between two sides of a scenario connected by a narrow corridor was published. The paper concludes that IR principles (in this case the robots create the traffic-controller institution) are superior to SR principles (simple behaviors and rules of interaction to avoid collisions in the corridor) when the number of robots and the length of the corridor increase.

We have also started an FCT project joining biologists, philosphers, computer scientists and engineers on related topics.

Cognitive architectures

Thesis: 1 PhD (Bruno Nery - ongoing), 1 MSc (Carlos Neves - finished)

Projects: 1 EU Project (RobotCub)



Robots are becoming part of our daily life and are being used by non-expert people. Therefore, they must be able to perceive the world, manipulate objects and interact with dynamic and unpredictable environments that were created

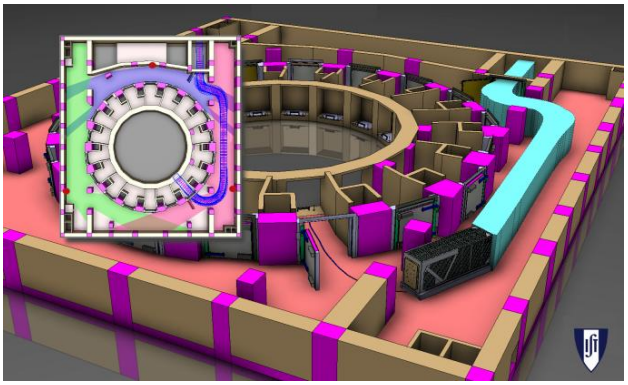
having people in mind. As these problems are not yet satisfactorily addressed by current approaches, we address the problem following a biologically inspired approach. One prominent approach when it comes to understanding how humans perceive the world and act on it comes from Hommel's Theory of Event Coding (TEC). The work carried on in this context consists on the development and validation of a cognitive robot architecture based on this theory and well-established tools within the framework of Bayesian theory. The architecture will be validated on the iCub robot platform.

The locomotion of a humanoid robot is a hard problem, in particular for the case of uneven terrains. Research has been carried out on locomotion strategies that are able to (1) detect local properties of the terrain, assuming it is locally flat, at this stage, and (2) adapt the locomotion gait to maintain balance.

Mobile Robots Navigation

Thesis: 1 MSc (João Ferreira – finished)

Projects: 1 Fusion for Energy (ITER TCS/ATS)



One of the biggest challenges in the present time is the production of clean energy with small environmental impact, while satisfying an ever growing consumption demand. Nuclear fusion power has potential to be a suitable alternative, given its capability to generate abundant energy, releasing no carbon dioxide or greenhouse gases. The International Thermonuclear Experimental Reactor (ITER) is an experimental fusion reactor, used to test fusion power process. ITER operation is centralized in a nuclear fusion reactor, the Tokamak, where a plasma is confined inside a Vacuum Vessel (VV), producing energy.

Maintenance operations of inspection and component replacement are required during the ITER lifetime. Therefore, operations of transportation are also required. Since no human being is allowed given the rad-hard conditions, the maintenance operations are remotely handled. The transportation of the required equipment is performed by a Transfer Cask System (TCS), with similar dimensions to an auto-bus, but the entire weight can reach 100 tons. The TCS is supported by an Air Transfer System (ATS), using an advanced set of air-cushion pads for moving through narrow corridors between the Tokamak Building (TB) and Hot Cell Building (HCB). Moving heavy loads in tight safety margins requires a precise localization system.
The navigation of these vehicles poses several challenges: first, the usage of sensors is severely limited by the presence of radiation, and therefore a sensor network of laser-range finders is being considered; second, the choice of trajectories given the constrained space of the TB; third, the control strategies to be used for the guidance of these vehicles; and fourth, the issues of human-robot interaction arising from the teleoperation of the robot.

Main achievements in 2010
In the project ITER TCS/ATS, complete studies on manoeuvres and parking of the TCS in the Tokamak and Hot Cell buildings were conducted. The specification of a test facility for a TCS prototype was carried out, including the required area, and the building and equipment requirements. Update of the Trajectory and Evaluator Software tool (TES) aiming at providing, in CATIA format, the volume occupied by the TCS vehicle when following a 2D path.

Field Robots

Thesis: 5 MSc (João Carvalho, Filipe Jesus, João Mendes, Rui Nunes, Marco Prata – all ongoing)

Projects: 1 FCT (HRI using interactive mapping and augmented reality)

Field robotics concerns the use of sturdy robots in unstructured environments. One important example of such a scenario is in Search And Rescue (SAR) operations to seek out victims of catastrophic events in urban environments. While advances in this domain have the potential to save human lives, many challenging problems still hinder the deployment of SAR robots in real situations.The approach taken here follows the principle of adjustable autonomy, in the sense of the teleoperator being able to define the level of the autonomy of the robots, ranging from direct manual guidance, up to the assignment of autonomous tasks, such as stair climbing and automatic docking. We also focus on the issue of human-robot interaction: endowing the human operators with an effective situation awareness, by the use of interactive 3D mapping and augmented reality methods.

1.2.2 Computer Vision Lab

Vision is the richest sensing modality that allows many living beings to perceive the surrounding world and act accordingly. It provides information with a large spatial resolution and reasonable temporal dynamics, while allowing the measurement of multiple types of properties of the visual world: color, texture, motion, shape, contrast, etc.

Computer vision and image analysis can thus enable a large number of applications, like 3D reconstruction, motion analysis, video surveillance and robotics, to name just a few. In addition, the massive deployment and cost reduction of cameras and the availability of low-cost, powerful processors have contributed to an increasing number of application opportunities.

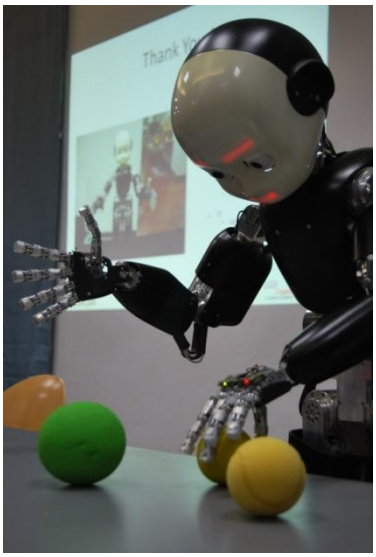
The research conducted at the Computer and Robot Vision Lab - Vislab has two main goals: (i) the development of new methodologies and tools for computer and robot vision and (ii) demonstrate such methodologies in challenging applications that call for such new tools. The research is organized in two main lines:

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

Several of the projects (ROBOSOM and HANDLE) on which we are involved are demonstrations of the interplay between engineering approaches, neuroscience and psychology where our work not only takes inspiration from findings in these fields but we really aim at providing new evidence and insight as to the way of functioning of the brain or biological systems.

In addition, we will be involved in a project in the CMU-Portugal Program in the topic of Robot and Sensor Networks and distributed decision making and mapping. We will focus mainly on the topic of human-robot interaction, namely, gesture recognition and human activity understanding.

a) Vision Based Control and Navigation



In this topic, we address the fundamental problem of understanding what *relevant* information can be extracted from an image sequence to *control* an artificial system (robot) in order to perform a *given task*. This line of research has been pursued for a long time in the VisLab, often with an emphasis on bio-inspired approaches. The biological inspiration is not only aimed at designing more flexible and robust artificial vision systems but also to help understanding biological systems through the process of modeling. The following research topics are currently being pursued:

- Visual Geometries: Natural vision systems have different geometries (e.g. compound versus corneal eyes). One of the research lines consists in designing non-conventional cameras (e.g. omnidirectional cameras, space-variant sensors) that may be more suitable for a class of visual tasks.

- Vision based control, Active vision and navigation: the active control of the visual sensors may ultimately constrain and simplify the recovery of visual information. The design of vision-based control systems has been tackled for a long time covering many types of robotic systems: mobile (land, air and underwater) vehicles, robotic heads, etc. We also exploit biological plausible representations of the environment that contribute to efficient navigation strategies.

- Learning and cognition: This line of research has evolved towards cognitive systems, with the ability to learn in an open-ended way from long periods of observation. One example lies in the area of human activity recognition from video as in e.g., video surveillance. Another example is the study of techniques allowing a complex system to develop and adapt over long periods of time as in e.g. humanoid robots. We have focused considerable research efforts on developing methodologies for humanoid robots to learn how to perform complex tasks through observation. This work has been undertaken in a tight collaboration with neuroscientists and developmental psychologists.

b) 3D Reconstruction, Motion Analysis and surveillance

The goal 3D motion analysis and reconstruction is to retrieve information about the scene structure (geometry) 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 is focused on the development of video surveillance systems able to understand human activities. The increasing number of cameras deployed in public spaces, makes it impossible for human operators to continuously monitor an overwhelming number of visual streams. We need systems able to interpret the human behavior in video imagery and call for the security operator attention only when an alarming event is observed. Further we apply similar approaches for human-robot interaction whereby non-verbal (gesture) communication can be a rich source of information.

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.

1.2.3 Signal and Image Processing

- Underwater acoustic communications and networking.
- Computer Vision, Visual object classification and recognition, Content-based image retrieval.
- Distributed Optimization in Sensor Networks.
- Distributed Detection and Estimation in Sensor Networks.
- Sensor Selection for Sensor Networks.
- Bilinear Factorization Methods for Computer Vision.
- Invariants for Image and Shape Representation.
- Machine Learning, semi-supervised learning approaches, distance metric learning approaches.
- Image Processing.
- Human Activity Recognition.

Medical Imaging, Ultrasound and Magnetic Resonance Imaging (MRI), functional Magnetic Resonance Imaging,
fMRI, Medical Signal Processing, Physiological modelling.

Engineering and Public Policy for networked industries, with emphasis on the telecom and on the energy sectors. Specific topics include, segmented regulation of wholesale markets for Next Generation Networks, Universal Service policy, the effects of broadband in schools on grades and IT penetration, social networks and churn, smart grids and integration of renewable sources of energy into the grid.

The underwater signal processing laboratory - SiPLAB at UALG - is dedicated to underwater acoustic signal processing, ocean acoustic tomography and underwater acoustic communications and networking. SiPLAB has approximately 15 researchers: 4 professors, 3 postdoc, 4 PhD students and 4 engineers. Its activities in underwater acoustics cover hardware development of sea going prototypes to support its research projects, methods and techniques for data analysis that directly exploit the developed hardware and at sea testing during international experiments. SiPLAB organizes and participates in approximately 1 or 2 sea trials per year in collaboration with its research partners. SiPLAB's main achievements encompass a record of publications of over 150 international papers both in journals and conference proceedings and the development of the Acoustic - Oceanographic Buoy (AOB) concept for network shallow water tomography. On going SiPLAB initiatives include the coordination of two FP7 projects and several national projects covering aspects of underwater wave energy devices acoustic noise monitoring, sea floor exploration and underwater acoustic networking including shallow water robust networks with fixed and mobile nodes.

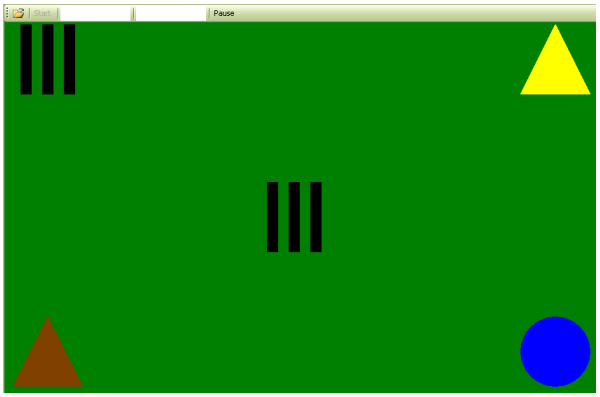
1.2.4 Evolutionary Systems and Biomedical Engineering

The research work of this group is currently focused on the new proposal of Linguistic Modelling through Rhythm Segmentation of the Electroencephalographic (EEG) signals of Human Sleep and on development, implementation and application of Neurofeedback based Brain Training and Neurophysiologic Therapy. The topic of biologically inspired new algorithms and paradigms for search and optimization has been extended. Current focus is on Evolutionary Algorithms for Dynamic Environments and Artificial Life Modelling and Simulations of Bio-systems and its application to Exams Timetabling. The potential application of the advances have been demonstrated namely on the definition of Peripheral Vision Indexes for Team Sports or Driving/Steering Machines.Advantages of using multiprocessor or multicell have been investigated as workhorse for Agent Based Modelling and Simulations Systems.

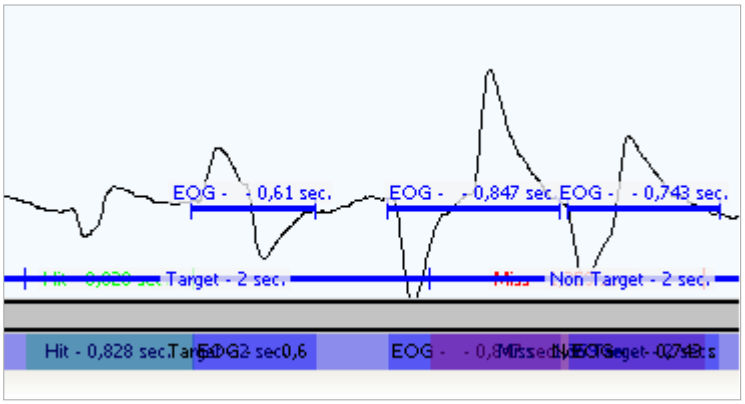
A few recent results will be presented below:

Evolutionary Peripheral Dynamic test for athletes

This study used a peripheral vision test that evaluates how well visual information captured in two different areas of the retina is used and tries to establish a relation with the performance of the test subjects in other fields. Automatic detection of ocular movement is used to distinguish between responses based on information from different retinal sites. Test subjects were athletes and were evaluated on how well they can recognize and relate objects in their peripheral and foveal field while focused on some different task. The correctness of their decisions based on this visual information is then compared to objective and subjective data on their athletic performance and other attributes.



Peripheral Vision Test Screen Layout 1



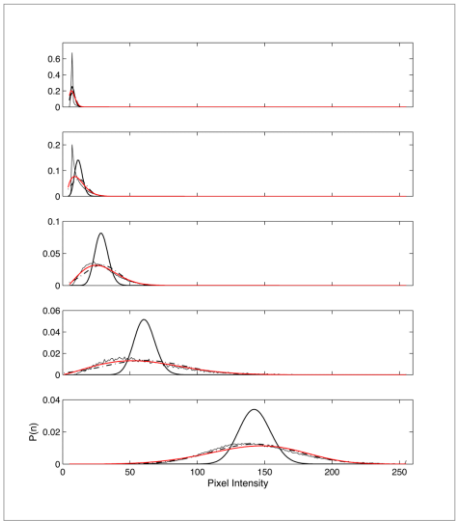
Electrooculogram recorded during Peripheral Vision Test and Eyes scanning movements detection.

$$PVscore = \frac{1}{2}\left[\left(\frac{TP}{T} - \frac{FP}{NT}\right) + \left(\frac{TN}{NT} - \frac{FN}{T}\right)\right] \times 100$$

Proposed Peripheral Vision Index

A statistical Pixel Intensity Model for Segmentation of Confocal laser Scanning Microscopy Images

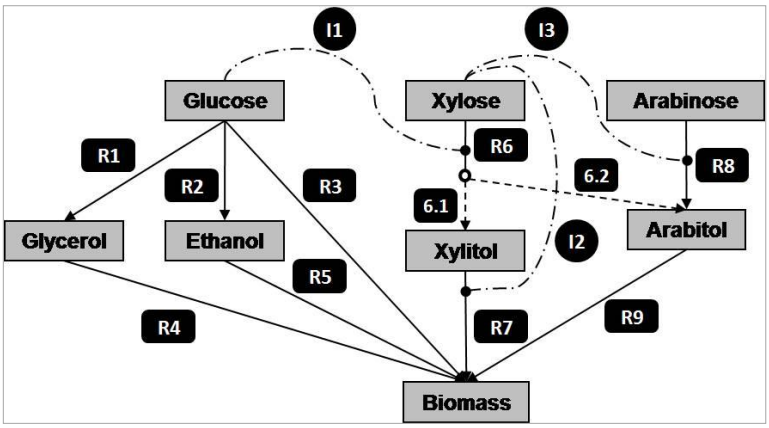
Confocal Laser Scanning Microscopy (CLSM) has been widely used in the life sciences and, because it allows the recording of the distribution of fluorescence-tagged macromolecules on a very thin region of the living cell, it is particularly suitable for the characterization of cell processes. For that purpose the identification of regions of interest through image segmentation is a required step. In many situations the complexity of the cellular structures or the amounts of data involved make it too difficult or inefficient to be done by hand. Considering the nature of CLSM images, statistically based segmentation methodologies appear as natural candidates. We propose a model to be used in the context of EM or ICM based unsupervised CLSM image segmentation.



Microbial Growth Models Parameter Estimation : *D Hanseni*

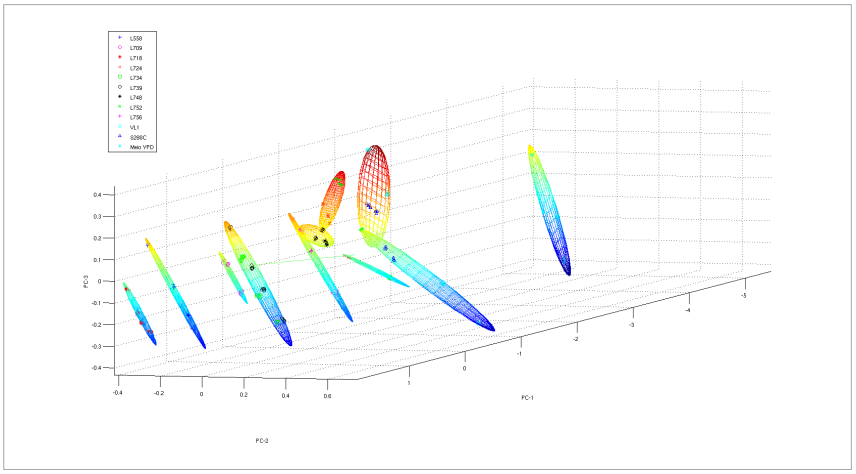
The model is derived from the CLSM image formation mechanics and compared to the existing alternatives. Results show that it provides a much better description of the data on classes characterized by their mean intensity, making it suitable not only for segmentation methodologies with known number of classes but also for use with schemes aiming at the estimation of the number of classes through the application of criteria like the MDL.

In this work we examined the performance of two evolutionary algorithms, a genetic algorithm (GA) and particle swarm optimization (PSO), in the estimation of the parameters of a model for the growth kinetics of the yeast *Debaryomyces hansenii*. Fitting the model's predictions simultaneously to three replicates of the same experiment, we used the variability among replicates as a criterion to evaluate the optimization result. The performance of the two algorithms was tested using 12 distinct settings for their operating parameters and running each of them 20 times. For the GA, the crossover fraction, crossover function and magnitude of mutation throughout the run of the algorithm were tested; for the PSO, we tested swarms with 3 different types of convergence behavior - convergent with and without oscillations and divergent - and also varied the relative weights of the local and global acceleration constants. The best objective function values were obtained when the PSO fell in the zone of convergence with oscillations or zigzagging, and had a local acceleration larger than the global acceleration.



Spectrometric signature differentiation of *Saccharomyces cerevisiae* strains

This document describes the application of several methods for differentiating *Saccharomyces cerevisiae* strains through their spectrometric signature. The problem has been approached with unsupervised data manipulation and clustering techniques, which range from off-the-shelf methods to algorithms specifically designed to handle the particularities of spectrometric data. Two other types of data, which share common characteristics with the yeast spectrometric data, are also subjected to the same type of analysis in order to assert the overall effectiveness of the different methodologies under study. Results indicate that the best approach for separating yeast strains consists of two steps: 1) perform dimensionality reduction of spectra using SVD or PCA; 2) cluster the projected data using either the EM algorithm or a novel approach based on hierarchical clustering with hybrid minimum volume and direction change linkages.



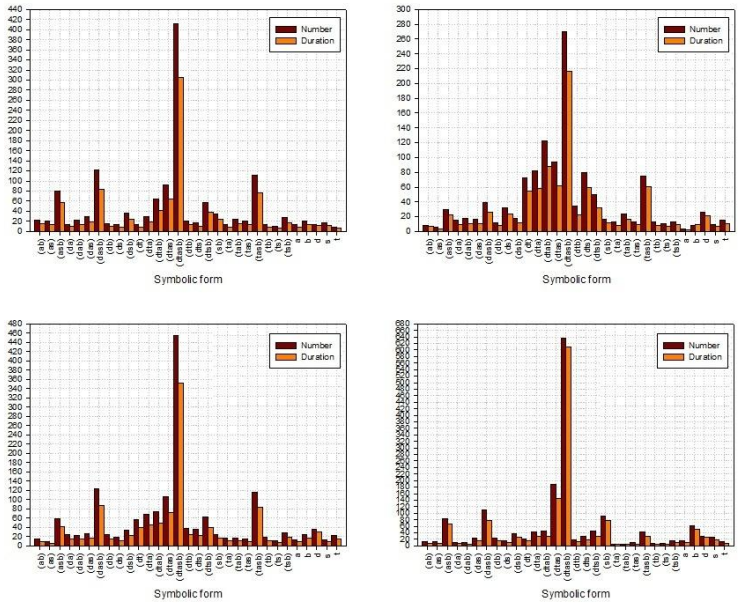
Symbolic Representation of the Sleep Electroencephalogram
Application in Analysis and Modeling of Sleep

This work presents a new methodology for sleep EEG signals' representation and is based on simple linguistics. This methodology is used in the analysis of sleep structure and modeling of whole night sleep and sleep stages; in the study of different populations, and classification of sleep patterns. All algorithms and methods applied into analysis of sleep are based on the analysis of single EEG channel from each subject.

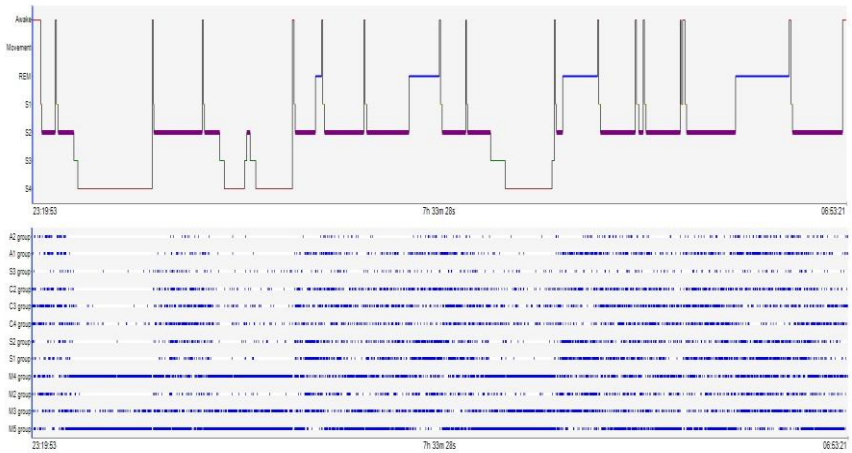
Two new algorithms for K-complex and artifacts detection are developed. Both algorithms are based on the thresholding techniques and used for the signals' preprocessing.

Methodologies for sleep representation, based on simple linguistics, and subsequent generalization of this representation, are proposed. Symbolic representation of sleep is based on the frequency characteristics of the EEG signals. New approach for the primary feature extraction, based on the thresholding technique, is presented. It separates EEG signal by its frequency bands and detects rhythms events. Detection is carried for each frequency band using optimal thresholds, which allow extracting as maximum information from the signal as possible.

Symbolically represented EEG signals are used in the analysis and modeling of sleep structure, and applied in the study of different populations.



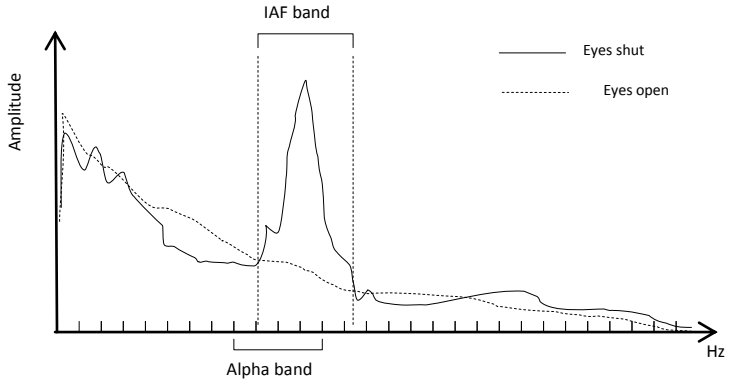
Grouped histograms for four different subjects. Axis y doesn't take into account different groups' scales and represents only values of the variables



Hypnogram and hypnomap from sleep EEG signal (subject 1, normal population).

EEGTraining Platform: Improving BCI interface control and cognitive skills

This work proposes a complete structure of an EEG biofeedback platform focused on an efficient way for its user to learn how to self regulate cortical activity. A longitudinal study of how voluntary training of specific electro cortical activity produces any stable changes in the electroencephalogram is also presented. Correlations of these changes with short term memory are also hypothesised. In this work the human brain was seen as an electrochemical machine capable of receiving stimuli and adapt accordingly. So, only relevant EEG activity was fed back to the trainee by a Brain Computer Interface (BCI) in an intelligible way, allowing the identification of phasic changes in the EEG and what cognitive state caused it. The results from this study showed that it is possible to learn to change some rhythmical activity in the EEG, in this case the alpha activity, after a few feedback sessions. A positive relation between this frequency band and cognitive processes was also observed. These results also indicate that the proposed EEG biofeedback protocol can be a powerful tool for those who rely on BCI to communicate with the external world as it allows the tracking and training of individual frequency bands.



Individual Alpha Frequency (IAF) and PAF

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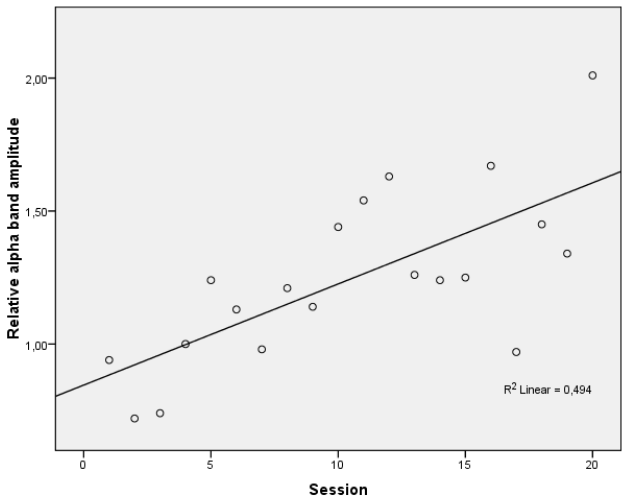


Correlation of IAF band amplitude with session number

1.2.5 Dynamical Systems and Ocean Robotics

Objectives

The key objectives of the R&D work carried out at the DSORL are twofold: i) to study a number of challenging theoretical problems in the areas of advanced robotic vehicle systems design, navigation, and control, and ii) exploit the theoretical methodologies developed to yield faster, cheaper, and far more efficient tools for ocean exploration and exploitation as well as critical infrastructure monitoring, than those available today. The tools include surface and underwater robots, as well as aerial vehicles working as communication relays or re-directing the operations of marine vehicles upon detection of relevant episodic events. These goals have motivated the definition of a research and development program addressing theoretical and practical engineering topics, as well as issues that are at the crossroads of marine science and technology, the main focus of the cooperative research and development work set forth under Thematic Area A. Two main lines of action underpin the work carried out at the DSORL:

1. Contributing to furthering the knowledge in the general area of dynamical system theory.

2. Developing new analysis and design tools in the areas of navigation, guidance, and control (NGC) and applying them to the development of advanced systems enabling the operation of multiple networked autonomous marine and aerial vehicles.

Theoretical Objectives:

A. Linear and nonlinear systems theory: study and development of theoretical tools for the analysis and design of linear and nonlinear control / filtering systems.

B. Robust Multiple Model Adaptive Control (RMMAC): Development of new methodologies for the design of robust adaptive controllers for plants with structured and unstructured uncertainty.

C. Design of Navigation and Positioning Systems for autonomous underwater platforms and human divers. Study of advanced solutions focusing on the: i) development of high performance, moderate cost heading and attitude reference units; ii) study and practical evaluation of acoustics-based systems for underwater vehicle positioning; iii) development of geophysical-based navigation algorithms.

D. Motion Control of single and multiple vehicles under stringent communication constraints, including those imposed by a very special medium: the ocean, with its plethora of phenomena that include multiple path effects, ray bending, and fading. Problems addressed: i) Motion control of autonomous vehicles with inner-outer loop control loops; ii) Visual servoing control; iii) Path Following; iv) Terrain Contour Tracking; v) Coordinated/cooperative control and navigation of groups of autonomous vehicles; vi) Diver assisted control by resorting to robot companions; vii) Networked control over faulty communication links.

E. Development of advanced methods for Cooperative Multiple Vehicle Mission Planning and Execution under energy and temporal constraints, in the presence of stationary and moving obstacles.

Practical Objectives:

A. Design and development of Autonomous Underwater Vehicles (AUVs), Autonomous Surface Crafts (ASCs), and Unmanned Air Vehicles (UAVs); with on-board integration of scientific sensor suites and data acquisition / logging systems.

B. Distributed hardware and software architectures for coordinated navigation and motion control of multiple vehicles as well as mission control of heterogeneous platforms.

C. Tests and scientific missions with the robots developed in cooperation with the scientific partners in Thematic Area A and other international institutions.

D. Dissemination actions for young students and the general public with the objective of bringing visibility to the challenging area of advanced marine /aerial robotics systems and their application to demanding scientific, surveillance, and security mission scenarios.

Main Achievements

Theoretical achievements

1. Further advances in the formulation of a Multiple-Model Adaptive Control (MMAC) architecture for linear time-invariant and time-varying plants subjected to structured and unstructured uncertainty, and sensor noise. The techniques yield - under certain conditions - closed loop robust stability and performance guarantees.

2. Study of new algorithms for control and state estimation on SE(3) to: i) extend the LQR problem to non-compact Lie Groups and ii) solve the state estimation problem of left-invariant dynamical system evolving on the special Euclidean group SE(3) with implicit output functions. These techniques have wide ranging applications in control and estimation of autonomous robotic vehicles equipped with vision systems.

3. Further developments on multiple model adaptive estimation (MMAE) and model identification (MMAI) methods that rely on a minimum energy criterion.

4. Further developments on a new methodology for multiple vehicle cooperative path planning to meet desired temporal and energy expenditure objectives, with due account for temporal or spatial deconfliction as well as communication and geophysical-based navigational requirements.

5. Further studies and assessment in simulation of the efficacy of a set of algorithms for cooperative motion control of multiple autonomous marine vehicles in the presence of communication failures, with due account for collision avoidance in dynamic environments.

6. Study and assessment (in simulation and through field tests) of the performance achievable with time-coordinated path following systems for multiple UAVs over time-varying networks using L1 adaptation (work done in cooperation with the Naval Postgraduate School. Monterey, CA and the Univ. Illinois, Urbana, USA).

7. Development of Lyapunov-based adaptive nonlinear control systems with application to the design of depth tracking and attitude controllers for underwater towed vehicles with parametric uncertainty.

8. Further development of new algorithms for AUV single beacon acoustic navigation in the presence of unknown ocean currents.

9. Improvement of the capabilities of “NetMarSyS: A Networked Marine Systems Simulator for Hardware-In-The-Loop Testing of Cooperative Multiple Vehicle Control and Navigation Systems” developed at the ISR/IST to assess the performance of advanced cooperative and navigation controlalgorithms prior to system implementation and testing at sea.

10. Study of nonlinear filtering structures for USBL tightly coupled inertial navigation and development of nonlinear GPS/IMU based observers for rigid body attitude and position estimation.

11. Derivation of a Rotorcraft image based controllers for extended flight envelope coverage. The proposed solution consists of a nonlinear state feedback controller for thrust and torque actuations that uses directly in the control loop the image features.

12. Further development of new methods to prove almost input-to-state stability (ISS) and almost global stability of nonlinear “rotational motion” systems by exploiting the combined use of Lyapunov Functions and Density Functions.

13. Development of algorithms for Nonlinear Attitude Estimation Systems Using Active Vision and Inertial Measurements, as applied to the problem of estimating the attitude of a rigid body equipped with a triad of rate gyros and a pan and tilt camera.

14. Further results on Networked Control Systems. New developments were obtained for a class of systems that is especially suited to model networked control systems utilizing CSMA-type protocols, with stochastic intervals between transmissions and packet drops.

15. Development of a new methodology for optimal placement of networked acoustic sensors to track multiple underwater targets by resorting to tools from estimation theory and multiple-objective optimization.

Practical achievements

1. Design, development, and test of an autonomous quadrotor for the inspection of critical infrastructures. This aerial vehicle, developed under the AIRTICI project, is equipped with video cameras and lasers that together with advanced control and navigation algorithms will allow the robot tooperate close to walls or under bridges without GPS.

2. Design, development, and test of an integrated Ultra Short Baseline (USBL) and Inertial Navigation System (INS) to be used as a low cost cooperative navigation system for underwater robotic vehicles. Preliminary sea tests were conducted in Sesimbra in the scope of the TRIDENT project.

3. Further development and testing of MEDUSA, an autonomous semi-submersible vehicle (SSB) that is being used in the scope of the EU CO3AUVs project. The vehicle is equipped with acoustic devices for underwater target tracking and complementary terrain-based / single beacon navigationexperiments.

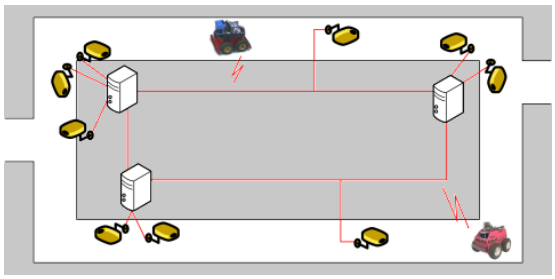
2 RESEARCH ACTIVITIES

2.1 RESEARCH PROJECTS

This section contains a brief description of the R&D projects in progress at ISR (Lisbon), IST and University of Algarve during 2010, under the supervision of ISR members.

Project name: **MAIS-S** - Multiagent Intelligent Surveillance System

Project leaders within ISR: Dr. Matthijs Spaan, Prof. Pedro Lima (IST/ISR)



Project description: With the generalized use of intelligent technology, the interaction between multiple smart devices poses interesting challenges both in terms of engineering and research. One interesting aspect of this phenomenon in the context of this project is the appearance of networks of heterogeneous devices that must operate in a fully distributed manner while sharing information necessary to complete some pre-assigned task. In this project, we propose that such complex networks be modeled as multiagent systems where each node corresponds to an agent. This interpretation suggests several interesting research avenues, some of which will be the focus of this project. We propose the use of a class of decision-theoretic models - Dec-POMDPs and specializations thereof - that naturally captures the decentralized nature of these networks in terms of local perception (the information that each node can acquire per se), interaction/communication (the exchange of information between the nodes) and local actuation (each node processes locally the available information and acts accordingly). In fact, one can argue that several systems typically considered in a fully centralized fashion (such as surveillance systems) could potentially benefit from this multiagent view of the network (e.g. in terms of robustness, more efficient communication, etc).

We are interested in heterogeneous surveillance networks that include different kinds of nodes, possibly with different perceptual and actuation capabilities, as well as different processing power. From this perspective it is natural, for example, to have nodes corresponding to cameras mounted on mobile robots. The control and even the positioning of the robots should be decided locally but in such a way to globally optimize the performance of the network.

The project will address the following problems:

- Scalability: General Dec-POMDPs have a worst case complexity that is NEXP-complete. As such, significant efforts have been devoted to finding simpler models that, while capturing the fundamental features of Dec-POMDPs, are still amenable to efficient computation. We explore how local interactions can simplify the process of decision making in these multiagent models.
- Efficient communication: We study the tradeoff between using communication to simplify the decision process against the cost of overloading the communication channels.
- Robustness: How should the network adjust when one or more of the nodes fail?
- Implementation: We investigate the problem of navigating the mobile robots as well as efficiently interfacing mobile and static nodes. We will implement a simple prototype of the system in a structured

environment (ISR), using an existing infrastructure, and we consider the possibility of conducting tests in a real scenario.

Research Areas: Planning under uncertainty, Dec-POMDPs, Reinforcement Learning
Project partners: INESC-ID, Instituto Superior Técnico (IST), ObservIt, CMU CS Department
Laboratories: Intelligent Robots and Systems Group, Robot and Computer Vision Lab
Initiated: September 2010
Concluded: Aug. 2013
Classification: CMU-PT/SIA/0023/2009

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Project name: **BioInstBots** - From Bio-Inspired to Institutional-Inspired Collective Robotics

Project leaders within ISR: Dr. Porfírio Silva, Prof. Pedro Lima (IST/ISR)

Project description: We seek to study and formalize laws that govern collective systems with the aim of synthesizing systems of relatively simple robots that display complex behavior individuals through local interactions. In order to achieve this endeavor, we will study both biological systems and social systems. From biology, we will focus on cell populations. A single cell is relatively simple when compared with a cell population such as a biological creature. While from sociology, we will focus on institutional economics (at the macro level, the agents can be treated as simple entities, no matter how sophisticated they may be at the micro level). Our objective is to bring together theories, ideas and inspiration from institutional economics and cell biology under a common formal framework for large robot populations modeling and analysis.

By the end of this project, we will aim at providing novel cooperation and coordination algorithms and methods for collective robotics based on a formal framework for collective systems. More specifically, we will import concepts from Biology and Economy and develop probabilistic mathematical models of the robot population dynamics under the different approaches (bio- and institutionally-inspired, and merged). This will allow us to gain further insight on their differences and similarities, relative merits, and adequateness for particular classes of systems, by predicting their performance in non-tested scenarios. Furthermore, though the project focus is on bringing multidisciplinary inspiration to design better robot collectives, we expect to provide further insight on cell biology and institutional economics mathematical modeling as a side effect.

Research Areas: Collective Robotics, Institutional Economics, Systems Biology
Project partners: Instituto Superior Técnico (IST), Instituto Gulbenkian de Ciência, ISCTE
Laboratories: Intelligent Robots and Systems Group
Initiated: Feb. 2010
Conclusion: Jan. 2013
Classification: FCT - PTDC/EEA-CRO/104658/2008
Project name: Perception-Driven Coordinated Multi-Robot Motion Control
Project leader within ISR: Prof. Pedro Lima (IST/ISR)

Project description: Several robotic tasks require or benefit from the cooperation of multiple robots: transportation of large-size objects, large area coverage (e.g., for cleaning) or surveillance (e.g., for fire detection), pollutant plume tracking, or target detection and tracking, to name but a few. In this project, we propose a novel active approach to cooperative perception through coordinated vehicle motion control. The vehicle formation geometry will change dynamically so as to optimize the accuracy of cooperative perception of a static or dynamic target by the formation vehicles. To achieve this, we will introduce innovative decentralized low-communication formation full state estimation methods, and dynamic-goal-driven formation control, for cooperative target localization and tracking by decentralized fusion of the data measured by all the formation vehicles.

We will also develop a novel embedded framework prototype to implement our contributions with low computational and power requirements, and test the proposed solutions in real robot scenarios, namely:

- heterogeneous outdoor (aerial + land) vehicle formations, for extended decentralized perimeter surveillance and intruder tracking/event detection, in hostile environments with limited-range terrestrial communications (border control, forest fire detection or search and rescue operations);
- heterogeneous (non-holonomic and omnidirectional kinematics, different vision systems) soccer robots with a common target (tracking a ball), in a highly dynamic and adversarial environment, often subject to occlusions and "kidnappings".

Real scenarios mean real wireless communications, plagued with link failures and limited bandwidth, and perception noise, often non-Gaussian, and subject to non-linear measurement and motion dynamic. Real robots and moving targets imply real-time requirements as well. We will also investigate methods that cope with all such constraints, namely reduced-dimension data representations (e.g., Gaussian Mixture Models), particle filter sampling of probability density functions, embedded frameworks that take into account power, communications and computational requirements, communications middleware to provide efficient use of the available resources, interoperability, heterogeneity abstractions, automatic re-configuration, and real-time communication protocols. Altogether we will explore simultaneously the complementary directions of coping with noisy perceptions and non-linear dynamics while improving the communications quality and system lifetime, maximizing the improvement in the global system performance.

Research Areas: Cooperative Localization and Perception, Formation Control
Project partners: Instituto Superior Técnico (IST), INESC-Porto, ISEP, FEUP
Laboratories: Intelligent Robots and Systems Group
Initiated: Jan. 2010
Conclusion: Dec. 2012
Classification: FCT - PTDC/EEA-CRO/100692/2008

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Project name: **Dec-PUCS -** Decentralized Planning under Uncertainty for Cooperative Systems

Project leaders within ISR: Dr. Matthijs Spaan, Prof. Pedro Lima (ISR/IST)

Project description: In this project we study planning under uncertainty for groups of cooperating multiagent systems. Developing intelligent robots or other real-world systems that plan and perform an assigned task is a major goal of Artificial Intelligence and Robotics. We develop general methodology and algorithms, and tackle two case studies relevant to society: multi-robot urban search and rescue, and irrigation channel control. In 2010 we obtained the following results. 1) We proposed a fast algorithm for optimally solving the one-step backup in Dec-POMDPs, and we have been building on this work to significantly improve the scalability of

optimal Dec-POMDP solvers. 2) We have been developing reinforcement-learning methods for multiagent and decentralized POMDPs, an area in which relatively little work has been published. 3) We presented a method for using auction protocols to achieve multi-robot coordination on a task level, by modelling each individual task as a POMDP. 4) We have been working on developing methods for multiagent planning under uncertainty for multi-robot systems. 5) We applied POMDPs in a search and rescue situation, where the aim of the problem is to find victims in a disaster environment.

Research Areas: Planning under uncertainty, POMDPs
Laboratories: Intelligent Robots and Systems Group
Project partners: Instituto Superior Técnico (IST)
Initiated: Oct. 2007
Expected conclusion: Sept. 2010
Classification: FCT - PTDC/EEA-ACR/73266/2006

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Project name: Activities Related To the Development of an Air Transfer System Prototype and Cask Transfer System Virtual Mock-Up (ITER TCS/ATS)

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

Project description: Remote Handling (RH) is an absolute required feature of ITER not only during nominal operation, but also during rescue and recovery situations. Among the various RH systems and sub-systems, a Transfer Cask System (TCS) has been adopted as the reference solution for the transportation of casks to/from vacuum vessel ports in all levels of the Tokamak Building (TB) and ports in the Hot Cell Building (HCB). The TCS is composed by a cask that enclosures the load, a pallet that holds the cask and an Air Transfer System (ATS) that is a mobile platform with a double set of pivoting drive wheels powered by electric motors, air-bearings and batteries on-board.

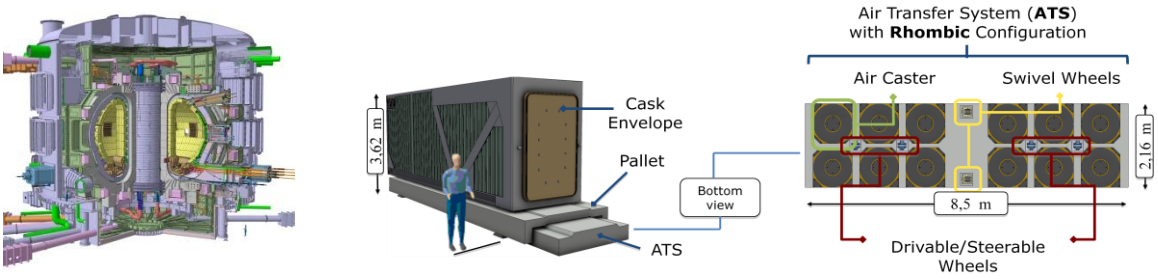

Fig. 1 - left: Tokamak Building; right: Transfer Cask System with its components

Developments and studies in the topic of path planning and trajectory following of the TCS/ATS inside the TB and HCB were performed by IST in 2009 in 2010, in the frame of this grant that started in March 2009. The TCS path optimization algorithm developed in 2008 was improved, incorporating optimization criteria to maximize the clearance to the closest obstacles and to guarantee the smoothness of the path. The algorithm was also extended to incorporate maneuvers, i.e., path topologies where the TCS stops to change its orientation.

The proposed planning algorithm for the TCS was applied in the latest models of the TB and HCB. A total of 63 trajectories were calculated: 46 trajectories in TB (28 without manoeuvres and 18 with at least a manoeuvre),

and 17 trajectories in HCB. For each trajectory, the distance to the closest obstacle along the TCS motion is evaluated, together with the proposed TCS velocity profile along the path. The TCS velocity is proposed to be proportional to the distance to the nearest obstacle with a maximum speed of 20 cm/s when the minimum distance is above 1 meter. Next figure displays a trajectory in the Equatorial level of TB with two manoeuvres, and the corresponding evolution of the distance to the closest obstacle and the velocity profile. Statistical results on the set of trajectories, with emphasis on their length and time duration were evaluated.

The MATLAB simulator that supports the design and performance assessment of the trajectories was greatly improved and is now a powerful and flexible tool for the generation of optimal paths for the TCS, easily accommodating changes in the building models and infrastructures (e.g., cable trays), and in the TCS and ATS dimensions. This tool will be extremely useful to support the expected future developments in terms of ITER buildings and TCS/ATS design.

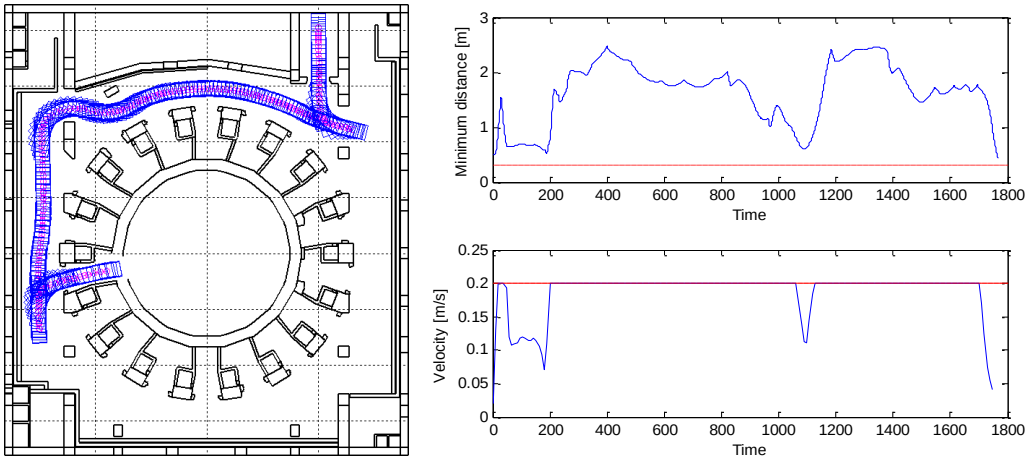

Fig. 2 - (left image) Trajectory between the lift and the vacuum vessel port cell 10 in the level B1 of Tokamak Building; and, (right image) the minimum distance between the TCS and the nearest obstacle and velocity along the trajectory.

Based on the study of the trajectories on the three levels of TB using the latest CATIA model, we at IST concluded that some building design might raise problems in terms of optimal and safe trajectories to/from the lift and all VV ports. In 29 VV port cell doors (11 in level B1, 10 in level L1, 8 in level L2), out of 46, the door's configuration in the CATIA model of TB prevented the generation of a safe trajectory. We proposed changes in the configuration of these doors, including changes in the aperture direction, the aperture angle, the location and the length. IST proposal was accepted by IO and is now under incorporation in ITER building design.

Studies on the location of parking areas, and the trajectories and the required maneuvers for parking were studied under the grant. A list of open issues related with the operation of the ATS/TCS was composed and provided to F4E. It will constitute future work within the group.

The specification of a test facility for an ATS/TCS prototype was completed together with CIEMAT. Based on the experience gained on the path generation topic, we compiled a list of tests that should be carried out in the test facility in what concerns the motion and docking of the ATS/TCS and the component transference in a port. Accordingly, the building and the equipment requirements were defined. The specified test facility has a minimum required are of 1200m^2, with the organization sketched in the figure.

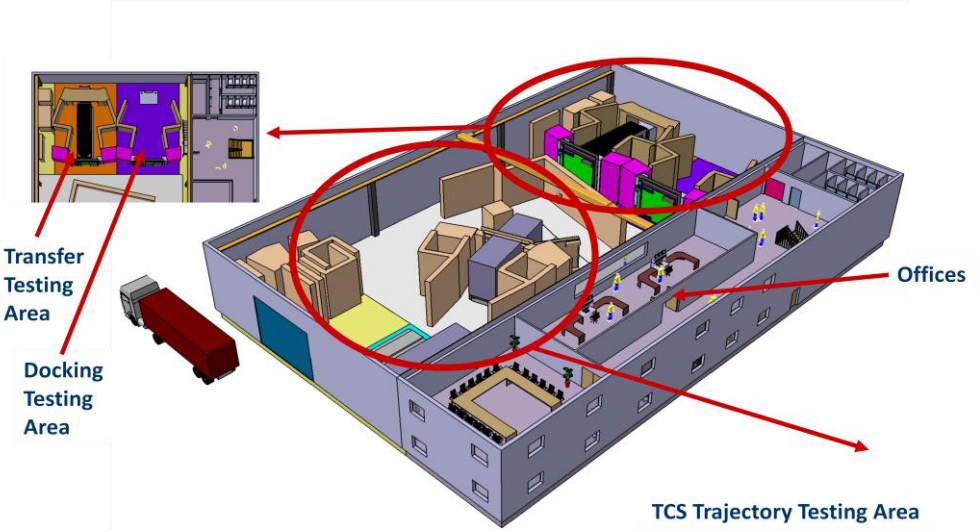

Fig. 3 - Specification of the TCS/ATS test facility

Technical consultancy support was given to F4E in various aspects of the ATS design. In particular issues that require future design attention were raised: non uniform dimension of all cask envelopes for the same pallet dimension, order of the procedures in a TCS docking operation, ATS and pallet connection. Additionally, technical aspects on wire guided navigation versus free-roaming navigation were carried out, together with a list of possible sensors to be used for TCS localization.

Given that the design of ITER, in particular the building design and space allocation, requires the volume occupied by all the components, IST developed a tool that, based on the paths defined in 2D, generates the volume occupied by the TCS along the optimal paths.

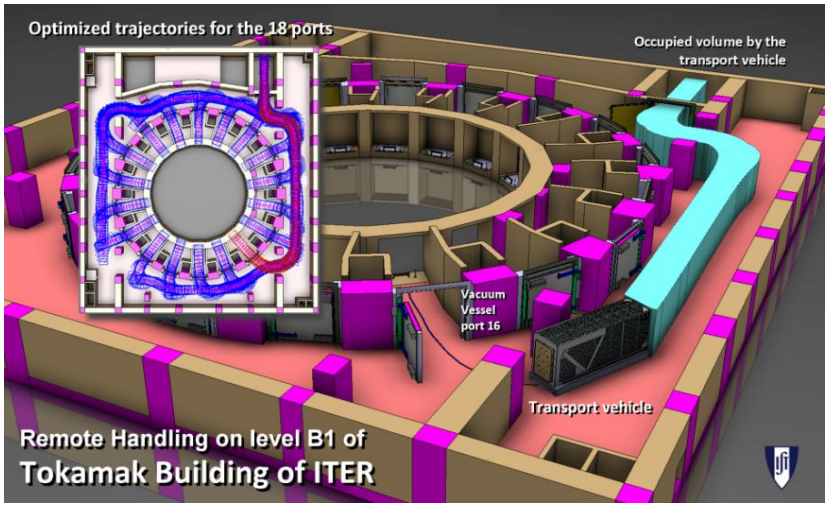

Fig. 4 - represents (left upper corner) the set of optimal trajectories and the area spanned by the TCS in the Divertor level of TB; volume occupied by the TCS along an optimal path.

Research Areas: Path Planning, Navigation, Teleoperation
Project partners: Instituto Superior Técnico (ISR/IST and IPFN/IST), ASTRIUM EADS (France), CIEMAT (Spain)
Laboratories: Intelligent Robots and Systems Group
Initiated: Mar. 2009
Expected conclusion: Jun. 2010
Classification: F4E-2008-GRT-016 (MS-RH)

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Project name: **SocRob -** Soccer Robots or Society of Robots

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

Project description: This project fosters general research on cooperative robotic systems, aiming at introducing methodologies for collaborative teamwork, driven by results from Multi-agent systems, Decision Theory in the presence of uncertainties and Discrete Event Systems. Its current case study is on Soccer Robots, with regular participations in RoboCup. The most relevant advances in this period concerned i) the upgrade of previously developed cooperative perception and object tracking using particle filters methods to improve their computational speed when running in the soccer robots, and ii).the first steps in using POMDPs in a practical problem, in this case having two robots playing soccer by selecting the actions that maximize their finite horizon expected cumulative reward, under partial state observation and uncertainty in the effects of robot actions.

Research Areas: Cooperative Perception, DES Plan Representation, Robot Task Modelling and Analysis, Cooperative Task Execution, Teamwork, Middleware and Architectures for Multi-Robot Systems
Laboratories: Intelligent Robots and Systems Group
Project partners: Instituto Superior Técnico (IST)
Initiated: 1997
Expected conclusion: N/A
Classification: N/A

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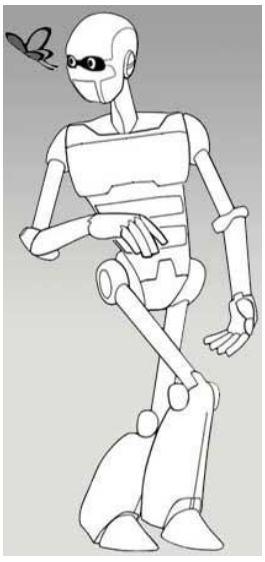
Project name: ROBOSOM – Robot Sense of Movement

Project leaders within ISR Prof. José Santos-Victor, Dr. Ricardo Ferreira



Project description: The objective of ROBOSOM is to investigate and to apply new approaches to the design and development of humanoid robots with advanced perception and action capabilities, showing robust, adaptive, predictive and effective behaviour in the real world.

The proposed new approaches are strongly based on the concept of human sense of movement by Alain Berthoz, a key partner in this project. There are two main ideas related to this concept, which are relevant to robotics: 1) the vestibular unified reference frame, as set by the vestibular system in the centre of the head; 2) Expected Perception (EP), or the capability to make predictions of consequences of actions, which is at the basis of the human predictive behaviour. The expected robot behaviour is the capability to follow a visual target by coordinating eye, head, and leg movements, with head stabilization,

walking smoothly and effectively in an unstructured environment, with a robust reactive behaviour, improved by predictions. This behaviour is a fundamental, but quite novel, capability for humanoid robots, and it may result in a truly robust and effective behaviour in many helpful tasks in real-world scenarios.

Research Areas: Computer Vision
Projectpartners: IST, SSSA (I), College de France (F); Waseda University (Japan).
Laboratories: Computer Vision Lab
Initiated: Dec. 2009
Expected conclusion: Nov. 2012
Classification: FP7 contract 248366 (STREP)

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Project name: FirstMM - Flexible Skill Acquisition and Intuitive Robot Tasking for Mobile Manipulation in the Real World

Project leaders within ISR: Prof. José Santos-Victor, Dr. Plinio Moreno

Project description: The goal of First-MM to build the basis for a new generation of autonomous mobile manipulation robots that can flexibly be instructed to perform complex manipulation and transportation tasks. The project will develop a novel robot programming environment that allows even non-expert users to specify complex manipulation tasks in real-world environments. In addition to a task specification language, the environment includes concepts for probabilistic inference and for learning manipulation skills from demonstration and from experience. The project will build upon and extend recent results in robot programming, navigation, manipulation, perception, learning by instruction, and statistical relational learning to develop advanced technology for mobile manipulation robots that can flexibly be instructed even by non-expert users to perform challenging manipulation tasks in real-world environments. designed to autonomously navigate in urban environments outdoors as well as in shopping malls and shops to provide various services to users including guidance, delivery, and transportation.

Research Areas: Computer Vision
Project partners: U.Freiburg (DE); FORTH (GR); KULeuven (BE); IST(PT); Fraunhofer-IAIS (DE); EPFL (CH), TUBerlin (DE); KUKA (DE).
Laboratories: Computer Vision Lab
Initiated: Feb. 2010
Expected conclusion: Jul. 2013
Classification: FP7 contract 248258 (STREP)

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Project name: HANDLE – Developmental pathway towards autonomy and dexterity in robot in-hand manipulation

Project leaders within ISR: Prof. Alexandre Bernardino

Project description: The HANDLE project aims at understanding how humans perform the manipulation of objects in order to replicate grasping and skilled in-hand movements with an anthropomorphic artificial hand, and thereby move robot grippers from current best practice towards more autonomous, natural and effective articulated hands. The project implies not only focusing on technological developments but also working with fundamental multidisciplinary research aspects in order to endow the robotic hand system with advanced perception capabilities, high level feedback control and elements of intelligence that allow recognition of objects and context, reasoning about actions and a high degree of recovery from failure during the execution of dexterous tasks.

This collaborative project is funded by the European Commission within the FP7, as part of theme 2: Cognitive Systems, Interaction, Robotics.

Research Areas: Computer Vision
Projectpartners: Univ. Pierre et Marie Curie (FR); Shadow (UK); Univ. Carlos III Madrid (ES); Univ. Coimbra (PT); Kings College london (UK); Orebro Univ (SE); Univ. Hamburg (DE); CEA (FR); IST (PT).
Laboratories: Computer Vision Lab
Initiated: Feb. 2009
Expected conclusion: Feb 2013
Classification: FP7 contract 231640 (IP)

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Project name: OBSERVFLY: Uninhabited Aircraft for Marine Science Applications

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

Project description: In recent years, there has been an increasing interest in developing and using Uninhabited Air Vehicles (UAVs) as tools for ocean surface data acquisition. However, the use of UAVs for ocean applications is still limited to a few scientific institutions scattered worldwide, and most vehicles have been designed to conduct simple survey missions that in general do not require close interaction between the operator and the environment. It is by now felt that the effective use of UAVs in demanding marine science applications must be clearly demonstrated, namely by evaluating the system in terms of adaptability to different missions scenarios, maritime launch and recovery, survivability, autonomy, endurance, payload performance and usability, and system integration with the existent marine science instrumentation. Meeting these stringent requirements poses considerable challenges to marine scientists, system designers, and developers.

This project represents a step towards meeting those goals. Specifically, it aims at developing a versatile UAV prototype that can take-off and land either on an opportunity airstrip (using the landing gear) or on a bay or harbour (as a seaplane). The aircraft will be designed for marine science applications with special emphasis on the location and tracking of marine mammals and commercially important or threatened pelagic species such as the Atlantic Tuna. Further applications include sea surface temperature measurement and specialized data acquisition for faster identification and better understanding of features like eddies and air sea interaction. The use of UAVs in marine science applications can be foreseen as tool for directing research vessels to new areas of interest, enabling a more efficient use of ship time.

The main focus of this proposal is on the design and construction of the aircraft itself, and on the development and integration of advanced systems for vehicle navigation, guidance and control, payload command, telemetry, and mission control. In preparation for future operation scenarios that can involve multiple air vehicles, additional research effort will be placed on the areas of flight formation and cooperative control of multiple UAVs.

System design, implementation and test will be guided by the requirements of a number of realistic mission scenarios, including those of two scientific missions devoted to tuna fish schools detection and cetacean location and tracking, to be undertaken in the Azores during the second and third years of the project. Laboratory pre-testing of the systems developed using hardware-in-the-loop simulation and flight testing of the complete UAV prototype in an airfield will precede the actual missions at sea. A predefined set of operational modes, which range from remotely operated to fully autonomous, will illustrate the capability of the aircraft and systems developed to perform the sequence of steps that are required to program and execute scientific missions in the ocean.

The avionic system for the UAV builds on similar systems that have been fully developed by members of the proposing team over the past few years. The degree of miniaturization achieved will make it possible to install the avionics in a small water proof container that can be easily mounted on and removed from the aircraft for inspection. To implement the avionics, a DSP based computer architecture is used, allowing for easy interfacing with the data acquisition hardware through a distributed architecture built around the CAN Bus and Ethernet. The Navigation System to be developed and installed onboard the UAV uses advanced aiding techniques to enhance error estimation in low-cost strap-down inertial navigation systems. New sensor-based control techniques resorting to a radar altimeter will be explored to implement terrain following controllers, thus enabling the vehicle to fly at a constant desired distance from the ocean surface or ground. Applications to automatic takeoff and landing maneuvers will be developed, implemented, and tested in the platform.

The UAV will also be instrumented with an image acquisition module, which consists of a digital video camera mounted on a pan-tilt unit. To deal with low frequency oscillations, a closed loop control system is used for stabilizing the image by commanding the pan and tilt motions of the camera based on inertial information available from the aircraft navigation system. It is then possible to ensure that the acquired images present a smooth behaviour so that a steady image of the ocean surface can be kept at all times, regardless of the pose assumed by the airplane while maneuvering or even under wind induced disturbances.

Research Areas: Navigation, Control, Robotics, Marine Biology
Projectpartners: Instituto de Sistemas e Robótica – Instituto Superior Técnico (P), Universidade dos Açores (DOP-UA)
Laboratories: Dynamic Systems and Ocean Robotics Lab
Initiated: 2008
Expected conclusion: 2011
Classification: FCT - PTDC/MAR/64546/2006

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Project name: AIRTICI: Advanced Interactive Robotic Tools for the Inspection of Critical Infrastructures

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

Project description: This project aims at the development of advanced robotic tools and techniques for the inspection of critical infrastructures. The cost involved in the construction and maintenance of critical infrastructures (CIs) like bridges, dams, overhead power lines, and industrial chimneys, the consequences of their failure or malfunction, do completely justify the existence of a periodic monitoring programme which helps in the risk evaluation and decision making process relative to the timing of the maintenance, or even repair, works.

A Helicopter for the inspection of CIs will be developed and its capabilities fully demonstrated in three realistic operational scenarios. The project brings together a multidisciplinary team with well proven expertise in a

wide range of key areas that range from the inspection of bridges and dams, using classical tools, aerial inspection of overhead power lines using video surveillance and laser based techniques onboard manned helicopters, industrial chimney inspection resorting to infrared cameras, computer vision, robotics, advanced systems for navigation, guidance, and control (NGC), and payload data acquisition and processing.

The team consists of three companies (HAGEN, LABELEC, and BRISA), one university (Instituto Superior Técnico), one technological institute (Instituto de Soldadura e Qualidade), a national laboratory (LaboratórioNacional de Engenharia Civil), and a prestigious research institute from France (Centre National de la Recherche Scientifique CNRS, Sophia Antipolis). The team reflects the objective of maximizing the incorporation of national competences at all scientific and technological levels, and simultaneously integrating the know-how of one of the world leader institutes in the area of Vertical Take-Off and Landing (VTOL) vehicles for the inspection of CIs.

Research Areas: Navigation, Control, Robotics, Civil Engineering.
Projectpartners: Hagen Engenharia, S.A. (PT), ISQ - Instituto de Soldadura e Qualidade (PT), Instituto de Sistemas e Robótica – Instituto Superior Técnico (P), LABELEC, Electricidade de Portugal EDP (PT), LNEC - Laboratório Nacional de Engenharia Civil (PT)
Laboratories: Dynamic Systems and Ocean Robotics Lab
Initiated: 2009
Expected conclusion: 2012
Classification: AdI

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Project name: SCARVE: Sensor-based Control of Aerial Robotic Vehicles

Project leaders within ISR: Doctor Rita Cunha (IST/ISR)

Project description: This project aims to develop and demonstrate the benefits of using sensor-based methods for motion control of aerial vehicles in uncertain and dynamic environments. Recent studies support anecdotal evidence that a wide variety of animals adopt motion strategies that rely on a perceptual invariant. Building on this notion, we propose to develop a sensor-based control framework for performing tasks that involve close interaction with the environment and require a reactive and compliant behavior in response to unexpected changes. Both single vehicle and multi-vehicle mission scenarios in three-dimensional space will be considered.
To devise sensor-based control algorithms, a connection between the control objective and an invariant mapped in sensor space will be sought after. For example, in a follow the-leader problem, a possible vision-based invariant is given by the image coordinates (as perceived by the follower) of a collection of feature points marked on the leader. A sensor-based perspective can also be adopted to approach the dual problem of vehicle state estimation. In this case, the key concept lies in exploring the dynamics of sensor measurements and combining them with the knowledge of the system to devise dynamic algorithms that progressively improve the position and orientation estimates as more data is collected.

To implement sensor-based strategies, we propose to build an aerial sensing testbed based on micro quadrotors. Given their handling qualities, these vehicles are ideal for operation in confined environments and present some advantages over other rotorcraft. They are similar to helicopters in that they can describe extremely agile maneuvers in the low speed regimes, including hover, vertical take-off and landing. When compared with the main-rotor tail-rotor configuration, the four-rotor configuration is more stable and allows for a considerable downsize in rotor diameter, which greatly reduces the risks to the safety of operation in enclosed spaces. Special emphasis will be placed on designing the smallest possible platform, while ensuring that the payload requirements are met. Reducing the size and weight not only makes for a safer low-cost vehicle but also simplifies and expedites the development and test process.

The intended applications focus on indoor or urban environments, where GPS signals are unreliable or simply unavailable so that the control algorithms must rely on local sensor information. The basic quadrotor configuration will be equipped with a small low-power computer, an inertial measurement unit, and an

ultrasonic range finder. Due to the payload constraints, either a camera or scanning laser range finder will also be installed onboard. We aim to address the topics of sensor-based control and navigation both from a theoretical and practical point of view. As such, we will concentrate not only on analyzing the stability and convergence of the proposed solutions but also on using the quadrotortestbed to demonstrate their applicability.

Envisaged tasks for a single vehicle include i) position and attitude stabilization with respect to a fixed target, ii) following a moving target, iii) tracking a specified feature in the environment keeping a security distance, iv) dynamic coverage of the working environment for data collection purposes. Multi-vehicle sensor networks open up a whole new ground of possibilities. Their spatial distribution and redundancy provide an extended sensory coverage ability and robustness to failure that can be exploited to surpass the capabilities of an individual vehicle. As an alternative to a single, complex vehicle burdened with equipment, a collection of smaller, less expensive, and simpler vehicles can increase efficiency and reliability, while reducing the costs of operation. Designing distributed algorithms for robotic networks poses unique challenges primarily related to the dynamic behavior of the sensing and communication topologies. Adopting a sensor-based approach, we will be concerned with accomplishing coordinated tasks such as gathering, pattern formation, or area coverage, using minimal communication between vehicles and relying mostly on the ability of each vehicle to sense the environment and the relative position of the surrounding vehicles.

Research Areas: Navigation, Control, Robotics.
Projectpartners: Center for Control, Dynamical-systems, and Computation - University of California Santa Barbara (USA), Instituto de Sistemas e Robótica –Instituto Superior Técnico (P)
Laboratories: Dynamic Systems and Ocean Robotics Lab
Initiated: 2010
Expected conclusion: 2013
Classification: FCT PTDC/EEA-CRO/102877/2008

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Project name: HELICIM: Autonomous Helicopter for Critical Infrastructure Monitoring

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

Project description: Structural health monitoring plays a major role in maintaining large critical infrastructures like bridges, breakwaters, dams, gas and water supply networks, and transport pipelines, which in general require complex and expensive routine inspections and maintenance procedures. Most of these structures are exposed to harsh environments and heavy loads and some of them (like rubble-mound breakwaters) are designed, due to their characteristics, under the proviso that maintenance and protection works will certainly be required during the structure's life. The cost of the structure, its expected behavior, as well as the consequences of its failure, do completely justify the existence of a monitoring program, which will help in the decision making process relative to optimal timing and extension of maintenance, or even repair, works. This process should be based on the structure diagnosis, which, in turn, should rely on a set of state variables that clearly characterize the health of the structure.

Accurate health monitoring and diagnosis of critical infrastructure will increase the efficiency of maintenance and repair plans, with inherent benefits in terms of cost reduction and damage minimization in case of disaster. This presents an opportunity for the development of advanced robotic surveying tools, namely uninhabited aerial vehicles (UAVs) equipped with state of the art laser, multi-spectral and hyper-spectral remote sensing devices, high accuracy inertial platforms, and positioning systems. These vehicles should be able to perform high accuracy tri-dimensional surveys of structures with the objective of producing, in real time, accurate data sets with the required spatial and temporal resolutions and thereby providing quantitative information vital for a well-founded diagnosis.

Recent advances in sensor technology and the increasing availability of computational capacity are steadily affording UAVs higher degrees of robustness and reliability in challenging operation scenarios, taking place in uncertain and possibly remote environments. Unlike fixed-wing aircraft, helicopters were designed to execute

vertical flight maneuvers, including hovering and vertical take-off and landing (VTOL). The trade-off for such maneuverability is an inherent complexity that translates into a highly nonlinear and unstable dynamical system with wide parameter variations over the vehicle's flight envelope.

Motivated by the foregoing considerations, the aim of this Project is to develop an Autonomous Helicopter specially tailored for critical infrastructure monitoring by means of collision avoidance mechanisms and absolute and sensor-based navigation and tracking control laws, which rely on the aircraft's advanced sensing devices and exploit the properties of the configuration space to express the dynamics of flying robots, that is the special Euclidean group SE(3). In preparation for future monitoring and inspection scenarios that can require the use of multiple helicopters equipped with complementary sensing devices, additional research effort will be placed on the area of cooperative control of multiple Autonomous Helicopters.

The development of such a system involves a wide range of research topics, including dynamic modeling and identification, navigation, guidance and control, real time systems, and mission control. This project team has already addressed some theoretical aspects of these topics within the scope of previous projects. Based on the work formerly developed, the current project will focus both on developing the experimental components and on extending the theoretical results previously obtained within the fields of guidance, navigation, and control. The resulting UAV will be equipped with a distributed real time computing network, a reliable wireless communication system, and sensing devices. Given the envisaged applications, the latter include inertial sensors, a GPS, a laser range finder, and a camera array composed by a digital video camera and an infrared camera.

The camera array will be mounted on a pan-tilt unit. To reject the low frequency oscillations induced by the vehicle and stabilize the camera's image, a closed loop control system will be implemented whereby the pan and tilt motions of the camera are compensated based on image data and inertial information provided by the aircraft's navigation system. It is then possible to direct the camera array to a specified target and ensure that it keeps a steady image, regardless of the pose assumed by the helicopter while maneuvering or even under wind induced disturbances.

The research work will focus on bridging the gap between theory and practice, by taking into account actual characteristics of the systems at hand in the development process. Evaluation of system components' reliability and of overall performance will be carried out in a controlled environment resorting to Hardware In-the-Loop Simulation to reduce both the number of required field trials and their associated risk factors.

Research Areas: Navigation, Control, Robotics.
Projectpartners: Instituto de Sistemas e Robótica – Instituto Superior Técnico (P)
Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: 2007
Expected conclusion: 2010
Classification: FCT - PTDC/EEA-ACR/72853/2006

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Project name: DENO: Development of Nonlinear Observers

Project leaders within ISR: Prof. António Pedro Aguiar (IST/ISR)

Project description: During the last few decades there has been an extensive study on the design of observers for nonlinear systems. An observer or estimator can be defined as a process that provides in real time the estimate of the state (or some function of it) of the plant from partial and possibly noisy measurements of the inputs and outputs and inexact knowledge of the initial condition. The aim of this project is to Develop Nonlinear Observers (DENO) that are provably accurate by construction. In particular, to assure that the research is driven by high-impact application areas, the DENO project will focus on the following class of nonlinear observers:
- Minimum-energy and H-infinity state estimators for systems with implicit outputs;
- Range observers;

- Multi-model adaptive estimators;
- State estimators of networked systems.

Research Areas: Navigation, Control, Robotics.
Projectpartners: Instituto de Sistemas e Robótica – Instituto Superior Técnico (PT), Center for Control, Dynamical-systems, and Computation - University of California Santa Barbara (USA), Instituto de Sistemas e Robótica - Universidade de Coimbra (PT)
Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: 2007
Expected conclusion: 2010
Classification: FCT - PTDC/EEA-ACR/67020/2006

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Project name: NAV: Development and Application of Advanced Nonlinear Control Techniques for the Coordination and Motion Control of a Network of Autonomous Vehicles

Project leaders within ISR: Prof. António Pedro Aguiar (IST/ISR)

Project description: The goal of this project is to develop, implement and test advanced robust control strategies for the coordination and cooperative motion a network of autonomous vehicles (NAV). The emphasis will be placed on the field of autonomous marine robots for two fundamental reasons: i) the highly nonlinear dynamics of marine vehicles pose formidable challenges to control system designers, and ii) autonomous marine vehicles are steadily becoming the tool par excellence to acquire scientific data at an unprecedented scale. However, the research done in the field of marine robots can certainly be adapted to land, air, and space vehicles.

The NAV-Control project combines two important and complementary components: fundamental research and applications. At a theoretical level, we propose to develop a set of control tools and algorithms that explicitly address the dynamics of the vehicles and the constraints imposed by the topology of the inter-vehicle communications network. Obtaining formal proofs of robustness and stability of the control algorithms is a key objective. At practical level, one key objective of NAV-Control is to build an experimental platform consisting of several low-budget tiny autonomous underwater vehicles (AUVs) (or semi-submersible AUVs) with embedded computing and communication capabilities, allowing them to perform cooperative tasks in a test tank. The testbed will allow for the simulation of different communication topologies and failures, two of the key issues that must be addressed at a theoretical level. Another objective is to assure that the research is driven by the high-impact field of marine robotics. It is expected that the methodologies and techniques developed in NAV-Control will contribute to the development of important tools for ocean exploration and exploitation.

Research Areas: Navigation, Control, Robotics.
Projectpartners: Instituto de Sistemas e Robótica – Instituto Superior Técnico (PT), Center for Control, Dynamical-systems, and Computation - University of California Santa Barbara (USA), Institute of Marine Research, Department of Oceanography and Fisheries, University of the Azores, Horta, Portugal (IMAR Açores).
Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: 2007
Expected conclusion: 2010
Classification: FCT - PTDC/EEA-ACR/65996/2006

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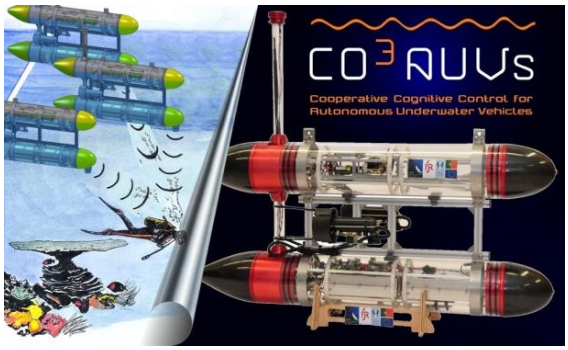
Project name: CO-3AUVs: Cognitive Cooperative Control for Autonomous Underwater Vehicles

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

Project description: Project description: The aim of the Co3-AUVs project is to develop, implement, and test advanced cognitive systems for coordination and cooperative control of multiple AUVs. Several aspects will be investigated including 3D perception and mapping, cooperative situation awareness, deliberation and navigation as well as behavioural control strictly linked with the underwater communication challenges. As a result, the team of AUVs will cooperate in challenging scenarios in the execution of missions where all data are processed online. In doing so, the team will be robust with respect to failures and environmental changes. These key features will be tested in a harbour scenario where additional difficulties with respect to open sea applications arise and in a human diver assistance scenario that also illustrates human robot interaction issues.



The EC CO3AUVs project: multiple robot-assisted diving operations

The MEDUSA semi-submersible autonomous marine robot at the EXPO 98 testing site (first prototype**)**

Research Areas: Navigation, Control, Robotics.
Projectpartners: GRAAL Tech SRL (IT), Instituto Superior Técnico (PT), Jacobs University Bremen, UniversitadegliStudi di Genova (IT)
Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: 2009
Expected conclusion: 2012
Classification: EU-FP7-ICT-231378

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Project name: FREESUBNET: Marie Curie Research Training Network

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

Project description: The purpose of FREESUBNET is to provide a European-wide excellence in quality training to young and experienced researchers in the emerging field of Cooperative Autonomous Intervention Underwater Vehicles (AUVs), which are steadily becoming the tool par excellence to carry out missions at sea without tight human supervision. In the scope of the network, an intersectorial consortium (HE, RES, and IND) with expertise in different but complimentary disciplines (engineering, marine science, physics and informatics) is carrying out outstanding research in the context of four strategic application fields (underwater archaeology, maritime security, marine science and energy assessment). The network aims to establish a bridge between academia and industry and to promote the integration of a number of research groups throughout Europe.

Research Areas: Navigation, Control, Robotics.
Projectpartners:15 Europeanpartners
Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: 2006
Expected conclusion: 2010
Classification: MRTN-CT-2006-036186

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Project name: **SIMBAD** – Beyond Features: Similarity-Based Pattern Analysis and Recognition

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

Project description: Traditional pattern recognition techniques are centered around the notion of "feature". According to this view, the objects to be classified are represented in terms of properties that are intrinsic to the object itself. Hence, a typical pattern recognition system makes its decisions by simply looking at one or more feature vectors provided as input. The strength of this approach is that it can leverage a wide range of mathematical tools ranging from statistics, to geometry, to optimization. However, in many real-world applications a feasible feature-based description of objects might be difficult to obtain or inefficient for learning purposes. In these cases, it is often possible to obtain a measure of the (dis)similarity of the objects to be classified, and in some applications the use of dissimilarities (rather than features) makes the problem more viable. In the last few years, researchers in pattern recognition and machine learning are becoming increasingly aware of the importance of similarity information per se. Indeed, by abandoning the realm of vectorial representations one is confronted with the challenging problem of dealing with (dis)similarities that do not necessarily obey the requirements of a metric. This undermines the very foundations of traditional pattern recognition theories and algorithms, and poses totally new theoretical and computational questions. In this project we aim at undertaking a thorough study of several aspects of purely similarity-based pattern analysis and recognition methods, from the theoretical, computational, and applicative perspective. We aim at covering a wide range of problems and perspectives. We shall consider both supervised and unsupervised learning paradigms, generative and discriminative models, and our interest will range from purely theoretical problems to real-world practical applications.

Laboratories: Signal and Image Processing Group
Research Areas: pattern recognition, computational learning
Project partners: Universitá Cá Foscari di Venezia, University of York, Technische Universiteit Delft, Universitá degli Studi di Verona, Eidgenoessische Technische Hochschule Zuerich.
Initiated: April 2008
Expected conclusion: March 2011
Classification: FT7-ICT-2007-C, grant 213250

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Project name: **MODI –** 3D Models from 2D Images

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

Project description: Motivated by applications in fields that range from robotics to virtual reality, the automatic generation of a 3D description of the real world environment has received the attention of a large number of researchers. Naturally, the use of expensive range sensors, i.e., sensors that provide explicit

information about the 3Dstructure of the environment in front of it, and/or accurately calibrated video cameras, has lead to successful results. However, in many cases only uncalibrated video images are available, due to either obvious economic reasons, or the specific nature of the applications, e.g., modern content-based representations for digital video. Inferring 3D content from 2D images has been one of the overall goals of the Computer Vision research field. In this project, we will step further toward that goal. Although the quest for the automatic understanding of 3D scenes has been around since the early days of Computer Vision, only recently, tools such as modernlarge-scale optimization techniques and statistical model-based methods, came into scene. In this context, we will addressthree main research topics: the correspondence problem, the analysis of non-rigid scenes, and featureless methods for 3Danalysis. In a general scenario, when inferring 3D content from a set of 2D images (obtained either by moving a single camera or by using a set of cameras), a key issue is the correspondence problem, i.e., the problem of determining which feature point in each 2D image corresponds to the same 3D point. This problem is usually solved in a local way, leading to inaccurate results. In opposition, we will use global constraints and develop non-convex large-scale optimization techniques to compute the globally optimal solution to the complete set of correspondences in a set of images. A crux of most approaches to the automatic inference of 3D content is the underlying assumption of scene rigidity. In fact, these approaches can not deal with time-varying object shapes, which severely limits their application, since, for instance, most biological shapes are intrinsically deformable (skin, organs) or articulated (bones). In this project, we seek to generalize the rigidity assumption and come up with optimization techniques able to deal with both problems of computing correspondences between 2D images and inferring 3D content, in a non-rigid world. The research line outlined above, as the majority of current methods, is based on an intermediate step that computes local features, e.g., image points. This intermediate step, in general computationally expensive, is often seen as the bottleneck of current solutions for the problem of inferring 3D models from 2D images. In contrast, featureless methods, i.e, methods that process directly the whole image data, without computing inter-image correspondences of pointwise features, have succeed in more constrained scenarios. In this project, we will use statistical modelling techniques to develop new featureless methods that provide partial descriptions of the 3D world. These descriptions will also enable innovative research lines that combine featureless methods with feature-based ones.

Research Areas: Computer vision
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2008
Expected conclusion: Dec. 2010
Classification: FCT - PTDC/EEA-ACR/72201/2006

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Project name: **ADDI** - Automatic computer-based Diagnosis system for Dermoscopy Images

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

Project description: Dermoscopy is a valuable diagnostic technique for the in vivo observation of pigmented skin lesions. This diagnostic tool allows for a better visualization of surface and subsurface structures and allows for the recognition of morphologic structures not visible by the naked eye. However, its application requires a long training and the final decision is often subjective. This project aims to build a fully annotated database of dermoscopic images for research and educational purposes i.e., training of clinicians. It will also develop a system for the automatic classification of skin lesions from dermoscopic images involving lesion segmentation, feature extraction and classification. This multidisciplinary project joins medical doctors from the Pedro Hispano Hospital (PHH) and academic researchers from different fields of Engineering and Mathematics.

Research Areas: Medical image analysis, dermoscopy.
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2010
Expected conclusion: Dec. 2012
Project partners: Universidade do Porto, Hospital Pedro Hispano, Universidade de Aveiro, Instituto Superior Técnico (IST).
Classification: FCT - PTDC/SAU-BEB/103471/2008

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Project Name: HEARTRACK - Segmentation and tracking of the human heart in 2D and 3D ultrasound data based on a principled combination of the top-down and bottom-up paradigms.

Project leader within ISR: Dr**.** Jacinto Nascimento (ISR/IST)

Project Description: The segmentation and tracking of the heart in ultrasound sequences is a challenging problem, which is still unsolved, in its full generality despite recent advances in this area. The main difficulties concern the presence of complex motion patterns of the heart and the low quality of ultrasound data mainly due to speckle noise, edge dropout effect caused by motion, the presence of shadows produced by the dense muscles, and the low signal to noise ratio. Most of the proposed solutions follow two trends: 1) the use of deformable model trackers based on low-level image features (e.g., edges) and 2) pattern recognition methods based on high-level visual features, automatically learned with the objective to minimize the probability of recognition errors. In the literature, the deformable models are usually called bottom-up approaches, while pattern recognition models are known as top-down approaches. This project proposes a combination of the bottom-up and top-down approaches for solving the problem of segmenting and tracking the left ventricle (LV) of the heart in 2-D ultrasound data. This will allow a significant improvement of previous methods since we are combining edge and motion information from bottom-up with visual appearance models used in top-down. Comparing with bottom-up, we expect to obtain improved robustness in the case of edge drop out and rapid LV motion as well as an automatic procedure for contour initialization. Comparing with top-down we will obtain a significant improvement since we will use additional sources of information given by the heart dynamic model and image edges. This approach will allow the reduction of the number of training images used in top-down, solving the major drawback of this class of techniques.

Research Areas: Image processing, Manifold Learning, Machine learning
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2010
Expected conclusion: Dec. 2012
Project partners: Instituto Superior Técnico (IST)
Classification: FCT **-** PTDC/EEA-CRO/103462/2008

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Project name: **ARGUS** - Activity Recognition and Object Tracking Based on Multiple Models

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

Project description: There are hundreds of cameras deployed in public places (e.g., streets, shopping malls, airports). However, most of the video information is stored or destroyed without being watched or

processed.. This project will develop a new representation for activity recognition. We assume that the object (e.g., person) trajectory is generated by a set of space-varying velocity fields learned from the video data. Different velocity fields correspond to different motion regimes. Therefore, switching is described by a field of space-varying stochastic matrices. The model addresses trajectory representation, model learning, application to activity recognition and the interaction among multiple pedestrians.

Research Areas: Video surveillance, Stochastic modeling of video data, Switched dynamical models.
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2010
Expected conclusion: Dec. 2012
Project partners: Instituto Superior Técnico (IST), Instituto de Telecomunicações (IT), INESC-ID
Classification: FCT - PTDC/EEA-CRO/098550/2008

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Project Name: VISTA - Vision based Touch Interaction Anywhere

Project leader within ISR: Dr. Jacinto Nascimento (IST/ISR)

Project description: Touch interaction is, nowadays, becoming pervasive. Mobile phones, tablet PCs, Microsoft Surface tables, large wall sized displays, are examples of the broad spectrum of devices who offer support for interaction techniques based on touch. This sample shows the great diversity that permeates these devices, from the multitude of sizes and form factors, to their hardware and software capabilities, including the possibility, in some of them, of exploring multi-touch gestures. However, one factor that still limits the penetration of this technology is its cost, most notably for the bigger devices. This is mostly due to the technological requirements of touch display technologies, which span resistive and capacitive panels, acoustic waves or pulse recognition, and, more recently, optical imaging, where two or more image sensors are placed around the edges (mostly the corners) of the screen. This project aims at introducing developments in order to further increase the availability and versatility of touch driven interaction surfaces, through gesture based interaction techniques, even extending the interaction scope by dropping the surface requirement. To achieve this goal we propose to use tracking of fingers (or any other object being grasped) accomplished by video captured by standard low cost video cameras or webcams. Additionally we aim to research new interaction techniques to explore the possibilities opened up by the proposed flexible interaction configuration.

Research Areas: Image processing and Informatics
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2010
Expected conclusion: September 2012
Project partners: Faculdade de Ciências (FCUL), Instituto Superior Técnico (IST).
Classification: FCT - PTDC/EIA-EIA/105062/2008

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Project name: PrintArt - Content and Ontology based Art Image Annotation and Retrieval

Project leaders within ISR: Dr. Alessio Del Bue – Prof. João Costeira (starting 2011)

Project description: This is a project that gathers researchers from the Instituto Superior Técnico, the Faculdade de Letras da Universidade de Lisboa, and the Museu Nacional do Azulejo with the purpose of designing a software to aid the study and the identification of Portuguese tile art.Mainly due to the ease of reproduction and transportation, prints were used as the favoured means to make pictures and information available throughout the world. In this way, these art works quickly reached the hands of craftsman which used them as sources of inspiration, replicating them in different media, among which the tiles are particularly noteworthy. Trademark of Portuguese culture, the tiles have been produced continuously for five centuries, benefiting from the original prints in composition and theme, but using them freely; changing proportions, adding and removing figures, simplifying or enriching backgrounds, inverting figures, among other things.The project aims to develop a tool that enables the cross-reference of information, matching prints and tiles, so as to identify the original sources of any given panel, as well as matching the tile panels and the figures portrayed in them.The final goal of this multidisciplinary project is the creation of a data base, available to help future research on Portuguese tile art.

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

Research Areas: Computer Vision, Image Retrieval, History of Art
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2010
Expected conclusion: Dec. 2013
Project partners: Faculdade de Letras da Universidade de Lisboa (PT), MNAz - Museu Nacional do Azulejo (PT)
Classification: FCT - PTDC/EEA-CRO/098822/2008

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Project name: URBISNET - Urban Environmental Networked Sensing using a Public Transportation Infrastructure

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

Project description: The main scientific goal of the URBISNET project is to develop tools for estimating a diffusive field, such as the concentration of gases over a certain area, using a set of mobile sensors. The operational goal is pollution monitoring in the city of Lisbon based on measurements taken by the fleet of public urban buses (Carris). This approach could significantly increase the density of sampling across the city with only a modest investment in infrastructure, thus providing a much more detailed picture of air quality than using the current small network of fixed measurement stations. A prototype system is being developed, comprising sensing/computing units installed on buses, a central station (CS) where data on the reconstructed pollution field will be made available, and all necessary components to convey readings through a vehicular network. The system will generate pollution maps with fine spatial and temporal resolution.

Research Areas: Air quality monitoring, sensor networks, vehicular networks
Laboratories: Signal and Image Processing Group
Initiated: Mar. 2010
Expected conclusion: Feb. 2013
Project partners: ISQ - Instituto de Soldadura e Qualidade (PT), IT - Instituto de Telecomunicações (PT)
Classification: FCT **-** PTDC/EEA-CRO/104243/2008

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Project name: Detection of Brain Microstates in Fibromyalgia

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

Project description: Fibromyalgia is a chronic syndrome of widespread pain and fatigue; its aetiology is still a mater of debate. It has been suggested that it is a psychosomatic response to psychological distress, but several underlying organic factors exist and symptoms have intriguing and ambiguous characteristics.

To our knowledge, this disorder is explained by the dissociated state concept. A dissociated state (DS) is a state that gathers characteristics from two functional states that shouldn't coexist. A clear example of that is alpha-delta sleep pattern. The presence of alpha rhythm pattern is typical from awake disappearing at sleep onset, while delta EEG patterns are characteristic of sleep. In FMS these two features coexist reflecting a "sleeping awake" state.

In this project will test the hypothesis that FMS is due to several brain-body DS, in which there are specific structures (thalamus, thalamo-cortical networks, hypothalamus and limbic system) and systems involved (thermoregulation and autonomic nervous system).

A brain microstate (MS) is a functional brain state (of neuronal populations) with finite duration, characterized by fixed spatial distribution and time-varying intensity. In this concern, we aim to describe the various functional MSs involved in different specific behavioral situations that incorporate FMS, namely, in sleep and awaked states, in physical exercise, in pain and pleasure feelings and in cognitive tests.

Research Areas: Neurosciences, Signal Processing and Data Mining, Fibromyalgia.
Laboratories: Signal and Image Processing Group
Initiated: Apr. 2010
Expected conclusion: Apr. 2013
Project partners: Instituto Superior Técnico (IST), Faculdade de Medicina de Lisboa.
Classification: FCT - PTDC/SAU-BEB/104948/2008

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Project name: Novel Information Processing Methodologies for Intelligent Sensor Networks

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

Project description: The main goal of this project is to address certain key research issues in the field of wireless sensor networks. More precisely, the expected outcomes of this project are:
1. Fast algorithms for sensor selection - we will develop fast (non-combinatorial) optimization algorithms for several sensor selection application scenarios which strike a desirable tradeoff among detection performance, computational complexity and robustness with respect to the fading wireless medium;
2. Secure WSN communication schemes - we will study the fundamental security mechanisms pertaining to the sensor network communications medium by exploiting tools from information theory. In addition to revealing the secrecy limits of wireless sensor networks, we will also construct specific transmission schemes appropriate to convey information between sensors and a fusion point in a reliable and secure manner, taking into account the energy and bandwidth restrictions of sensor networks;
3. Secure Control of Cyber-Physical Systems - we propose to introduce a new approach to control systems design, by formally defining security attacks on control systems and by developing tools to analyze the effect of security attacks, to design attack resilient control systems and develop quantitative metrics to assess the natural tradeoff between security and performance.

Research Areas: Wireless Sensor Networks, Distributed Estimation and Detection, Information Theory, Control of Cyber-Physical Systems
Laboratories: Signal and Image Processing Group
Initiated: Nov. 2010
Expected conclusion: Oct. 2013
Project partners: Instituto Superior Técnico (IST), Instituto Sistemas e Robótica (ISR), Instituto de Telecomunicações (IST), Carnegie Mellon University (CMU), Intelligent Sensing Anywhere (ISA).
Classification: CMU-PT/SIA/0026/2009

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Project name: **TMP** – Telecom Technology. Management and Policy

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

Project description: This project looks at the deployment of Next Generation Networks. We study how regulation must adapt to balance investment and competition. We look at how wholesale markets can be regulated and how to ensure that universal service migrates towards broadband. We also look at mobile operators and cell phone networks. Here, we are particularly interested in characterizing and predicting contagious churn.

Research Areas: Telecom policy, segmented regulation, universal service policy, social networks
Laboratories: Signal and Image Processing Group
Initiated: Oct. 2009
Expected conclusion: Dec. 2011
Project partners: Instituto Superior Técnico (IST), Faculdade Ciencias Economicas e Empresariais da Universidade Catolica Portuguesa, Carnegie Mellon University, Portugal Telecom, Vodafone Portugal
Classification: CMU-PT/NGN56

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Project name: **WESP** – Weaving Together Human Interaction, Social Networks and Telecom Policy

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

Project description: This project is aimed at understanding how social networks impact people's lives and interactions taking into account human factors, which in turn should be factored into building up new interfaces for mobile devices rich in media content. This project also looks at the impact of new networks, such as P2P, to transfer media across peers and studies the social and economic impact of using such networks to illegally exchange copyrighted materials.

Research Areas: Telecom policy, interfaces and social networks
Laboratories: Signal and Image Processing Group
Initiated: Oct. 2009
Expected conclusion: Dec. 2011
Project partners: Instituto Superior Técnico (IST), Faculdade Ciencias Economicas e Empresariais da Universidade Catolica Portuguesa, Universidade da Madeira, Carnegie Mellon University
Classification: CMU-PT/SW14

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Project name: LUI – Lead User Innovation

Project leaders within ISR: Prof. Pedro Ferreira (IST/ISR)

Project description: The objective of this project is to study how user led innovation in the ICT industry develops. User led innovations have been shown, consistently and across industries, to be more successful than manufacturer innovation. In this project, we aim at testing this hypothesis in the services sector and in ICTs. We also aim at understanding how open access platforms help user innovation and whether social networks help reach market critical mass faster.

Research Areas: Telecom policy, innovation in telecoms, user innovation
Laboratories: Signal and Image Processing Group
Initiated: Oct. 2010
Expected conclusion: Dec. 2012
Project partners: Instituto Superior Técnico (IST), Faculdade Ciencias Economicas e Empresariais da Universidade Catolica Portuguesa, Carnegie Mellon University, Nikola-Tesla, Nokia Siemens Networks
Classification: CMU-PT/SW34

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Project name: **IMASEG3D** – Learning to Combine Hierarchical Image Modeling with 2-D Segmentation and 3-D Pose Recovery of Visual Objects

Project leader within ISR: Dr. Gustavo Carneiro (IST/ISR)

Project description: The field of statistical pattern recognition of visual information using digital images is experiencing a boom of scientific discoveries and technological applications. The ultimate goal of this field is to make computers "understand" a scene captured with a digital camera, in the following way: given a still picture, how can a computer automatically identify what is present (image annotation and context identification), and estimate the 3-D pose and segmentation of the visual objects. The solution to this problem involves the reverse engineering process of how an image is formed. This process comprises an analysis that estimates a 3-D model that may have generated the scene, followed by its verification in the image. This problem is essentially ill-posed because several different models (i.e., different interpretations) can lead to similar pictures. Therefore, the computer has to decide on the most likely model (among several ambiguous models) using image features, statistical models of visual objects, and relations between visual objects to constrain the complex search space for scene interpretations. This application introduces a proposal for a novel methodology to solve the problem above based on a principled probabilistic model that combines hierarchical context classification, visual class recognition, 2-D segmentation, and 3-D pose recovery from 2-D images. This project is relevant for the scientific community and for the industry. For the industry, the technologies developed in this project can improve the accuracy of image search and annotation systems, such as Google images, Yahoo images, Theseus, and Quaero. For the scientific community, the 3-D model abstraction will allow for the recognition of new visual classes with consistent shape information and varying appearance. Moreover, the use of multi-level hierarchical models can lead to efficient search methods in very large databases, and a more effective visual context abstraction.

Research Areas: Computer Vision, Machine Learning, Content-based Image Retrieval
Laboratories: Signal and Image Processing Group
Initiated: Mar. 2010
Expected conclusion: Mar. 2012
Project partners: Instituto Superior Técnico (IST)
Classification: PIIF-GA-2009-236173

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Project name: **SIPM** – Signal and Image Processing on Manifolds

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

Project description: The broad objective is to produce new theoretical/practical tools to tackle real-world problems on manifolds. Theory: the objective is to establish fundamental results (application-independent). Main topics are: (a) performance limits and (b) models for stochastic time-series. (a) The objective is to generalize the Cramér-Rao bound to the context of Riemannian manifolds. (b) The objective is to extend Euclidean models (e.g. AR, MA, etc) in order to create similar building blocks for time-series analysis on manifolds. Another topic to be addressed is manifold learning. Practice: the objective is to derive new algorithms for key problems on manifolds. Main topics are: (a) centroid computation and (b) optimization of nonsmooth functions. (a) The objective is to create Newton like algorithms for computing the Karcher mean of constellations on manifold. (b) The objective is to study certain nonsmooth optimization problems (e.g. image restoration) from the differential-geometric viewpoint.

Research Areas: Optimization, Riemannian Manifolds, Matrix Completion Problems
Laboratories: Signal and Image Processing Group
Initiated: Jan. 2008
Expected conclusion: Dec. 2010
Classification: FCT - PTDC/EEA-ACR/73749/2006

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Project name: **ESONET** - European Sea Observatory Network

Project leader within ISR: Prof. Sérgio Jesus (UALG/ISR)

Project description: ESONET is an European Network of Excelence involving over 50 European institutions during 4 years with the aim of laying down the plans and necessary standards for a future network of land connected sites for ocean observation throughout Europe, from the North Sea to the west Mediterranean. This project is financed by the EU under FP6 programme, with 7.5 Meuros for 4 years.
URL: http://wwz.ifremer.fr/esonet_emso

Research Areas: ocean circulation, climate, biology, bio-acoustics, geophysics.
Laboratories: Signal and Image Processing Group
Project partners: IFREMER (coordinator), ULB, IO-BAS, ALCATEL, ATLANTIDE - ALTRAN OUEST, CNRS, CNRS – LOV, CNRS – CEREGE, CNRS – CPPM, CNRS – IUEM, CNRS – LMGEM, IPGP, NKE, SERCEL, Océanopolis, KDM, IFM – GEOMAR, AWI, JUB, MPIMM, NSW, SEND, SIS, TFH Berlin, HCMR, FORTH, IMI, CSA, CNR – ISMAR, INFN, INGV, TECNOMARE, TESEO, FUGRO, NIOZ, UiT,NGI, NERSC, CINTAL, FFCUL, DOP-Uaç, UALG, CSIC, UPC, DBSCALE, UGOT, SU, B.U.,KOERI, DEU-IMST, ITU-EMCOL, GURALP SYSTEMS LTD, NERC-NOC, UNIABDN.
Initiated: March 2007
Expected conclusion: Feb. 2011
Classification: FP6-SUSTDEV SUSTDEV-3 Global change and ecosystems

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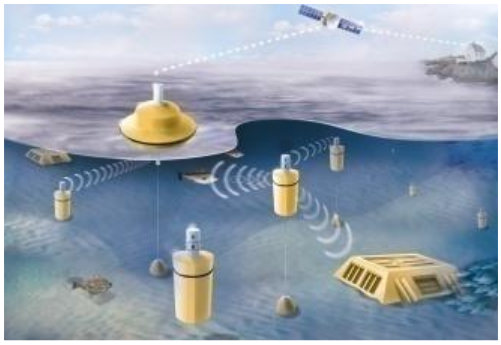
Project name: **UAN** – Underwater Acoustic Network

Project leader within ISR: Prof. Sérgio Jesus (UALG/ISR)



Project description: UAN objective is to conceive, develop and test at sea an innovative wireless network integrating submerged, terrestrial and aerial sensors for the protection of off-shore and coastline critical infrastructures. This project is funded by EU under FP7 Collaborative project ICT/Security with 2.95 MEuro for 3 years.
URL: http://www.siplab.fct.ualg.pt/proj/uan.shtml)

Research Areas: Underwater communications, infrastructure protection
Laboratories: Signal and Image Processing Group
Project partners: CINTAL, SELEX, SINTEF, ISME, FOI, KM
Initiated: Oct. 2008
Expected conclusion: Sept. 2011
Classification: FP7 Collaborative project ICT/Security

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Project name: **OAEx** – Ocean Acoustic Exploration

Project leader within ISR: Prof. Sérgio Jesus (UALG/ISR)

Project description: OAEx is an exchange project funded under the EU Marie-Curie initiative that aims at reinforcing links, exchanging experiences and methodologies between european and non-european partners in the field of ocean exploration using acoustics. This project is funded by EU under FP7 IRSES program with 187.2 kEuro for 3 years.

URL: http://www.siplab.fct.ualg.pt/proj/oaex.shtml

Research Areas: Collaboration, underwater acoustic monitoring and communications
Laboratories: Signal and Image Processing Group
Project partners: CINTAL - Centro de Investigação Tecnológica do Algarve (beneficiary), ULB - Université Libre de Bruxelles (Belgium), COPPE - Universidade Federal do Rio de Janeiro (Brasil), IEAPM - Instituto de Estudos do Mar Almirante Paulo Moreira (Brasil) and C-MARS Canadian Marine Acoustic Remote Sensing Facility (UVic, Canada).
Initiated: Feb. 2009
Expected conclusion: Dec. 2011
Classification: FP7-PEOPLE-IRSES-2008 Marie Curie Action "International Research Staff Exchange Scheme"

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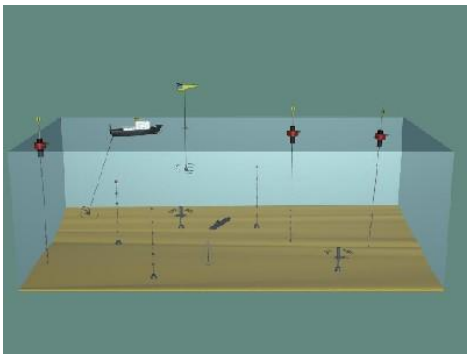
Project name: **PHITOM** - Probabilistic High-Frequency Ocean Tomography for Underwater Communications and Navigation

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

Project description: The project aims at developing and applying techniques of ocean acoustic tomography to the high-frequency signals used in digital communications incorporating into the receiver some awareness of the environment and the spatial configuration of the acoustic link that is almost totally lacking in current underwater modems. Having this capability built into the receiver is very appealing, e.g., for localization and navigation.

URL: http://www.siplab.fct.ualg.pt/proj/phitom.shtml



Research Areas: Underwater acoustics, Wireless communications
Laboratories: Signal and Image Processing Group
Project partners: Instituto Superior Técnico (P), CINTAL/ UAlg (P).
Initiated: Dec. 2007
Expected conclusion: May 2011
Classification: FCT - PTDC/EEA-TEL/71263/2006

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Project name: **WEAM** - Wave Energy Acoustic Monitoring

Project leader within ISR: Prof. Sérgio Jesus (UALG/ISR)

Project description: the project aims at developing, testing and validating a monitoring system for determining underwater acoustic noise generated by wave energy-based generators and its impact in the sea fauna. This study will be able to extend noise predictions to farms of wave generators with pre-determined configurations.
URL: http://www.siplab.fct.ualg.pt/proj/weam.shtml

Research Areas: Acoustic environmental monitoring, acoustic tomography
Laboratories: Signal and Image Processing Group
Project partners: Wave Energy Center, CINTAL:
Initiated: Nov. 2007
Expected conclusion: Oct. 2010
Classification: PTDC/ENR/70452/2006

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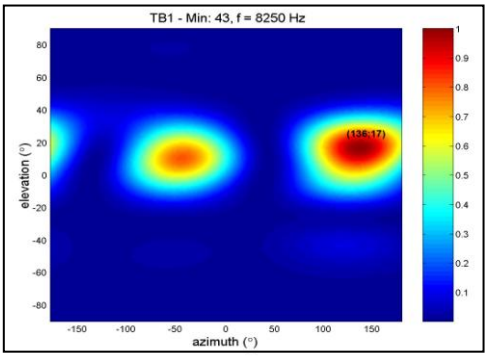
Project name: **SENSOCEAN**

Project leaders within ISR: Prof. Paulo Felisberto (UALG/ISR)

Project description: the project aims at developing an acoustic vector sensor array (VSA) for an underwater mobile platform (AUV) with application in acoustical exploration of the marine environment. Acoustic vector sensors measure both pressure and the three components of particle velocity.

URL: http://www.siplab.fct.ualg.pt/proj/sensocean.shtml



Research Areas: compact systems, sea bottom exploration.
Laboratories: Signal and Image Processing Group
Project partners: CINTAL
Homologado: November 2009
Expected conclusion: December 2012
Classification: FCT - PTDC/EEA-ELC/104561/2008

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Project name: **Smart Vision** – An Active Vision Aid for the Blind

Project leader within ISR: Prof. Hans du Buf (UALG/ISR)

Project description: Develop the necessary technology for outdoor and indoor navigation, with obstacle avoidance and object recognition. Main problems to be solved are the detection of outlines of sidewalks and zebra crossings while walking, including nearby obstacles like trees, traffic signs, persons (children) and dogs. Indoor navigation requires detection of corridors, doors and furniture, but also locating objects, like a ketchup bottle in a pantry or fridge. The necessary hardware is already available: a palmtop with BlueTooth link and GPS (in the future Galileo), plus cameras with USB interface. The main problem of a palmtop is its processor without floating-point units, which means that state-of-the-art algorithms from computer vision must be implemented using integers. There are two solutions: (a) most of the processing can be done remotely on a normal PC or even a small cluster, and (b) instead of applying most processing from the first to the last pixel of the video frames, processing can be limited to important regions by using a model of human vision, namely Focus-of-Attention (FoA). Instead of only focusing on computer vision, this project establishes a link with human vision. Recent progress in the modelling of processes in the visual cortex showed that computational models can already compete with the state-of-the-art in computer vision. This concerns 2D multi-scale line/edge and keypoint extraction, Focus-of-Attention and object categorisation.

Research Areas: Human Vision, Computer Vision, Visual Cortex, Attention, Categorization, Recognition, Navigation.
Laboratories: Signal and Image Processing Group (Vislab/UALG)
Project partners: CINTAL (UAlg), UTAD, AIBILI (UC), IST
Initiated: Jan. 2008
Expected conclusion: Dec. 2010
Classification: FCT - PTDC/EIA/73633/2006

♦

Project name: Neural Correlates of Object Recognition: Structure-function Correlations within the Visual Ventral Stream, Striatal and Limbic Circuits in Health and Disease

Project leader within ISR: Prof. Hans du Buf (UALG/ISR)

Project description: In order to directly address the role of different brain structures in object recognition, we will first use functional magnetic resonance imaging and high density event-related electrophysiological recordings. We plan to study responses to neutral and standard emotional faces that that have been morphed between distinct levels of relative emotions. The morphing procedure will allow for the implementation of a parametric neuroimaging design that will enable to isolate how specific are the neural networks processing facial expressions of fear and disgust and how prone they are to hysteresis. As identification of sigmoidal BOLD neuroimaging response profiles will help define a clearcut separation between such networks we do believe that our experimental paradigm will help solve the current debate on the separability of such circuits. We do believe that functional connectivity is better addressed if one studies perceptual decision using incomplete, ambiguous test stimuli with contradictory content. This type of paradigm was previously used in our own research in the context of object/surface segmentation. We will apply these paradigms both in normal subjects and in clinical models of striatal and amygdala dysfunction (Parkinson&Huntington disease and Williams Syndrome (WS), respectively). Symptomatic Huntington's disease patients are impaired in interpreting facial and vocal expressions of disgust although recognition of other emotions is also affected. To ensure that the role of the caudate nucleus is specifically addressed, we will study pre-symptomatic HD carriers, as well as patients in early disease stages. Behavioral measures (eye movements, reaction times, recognition scores) will be correlated with neuroimaging (structural/functional) measures concerning striatal structures.

Research Areas: Psychology, Human vision, Visual cortex
Laboratories: Signal and Image Processing Group (VisLab/UALG)
Project partners: AIBILI (UC), FM (UC), Univ. Aveiro, CINTAL (UAlg)
Initiated: Nov. 2007
Expected conclusion: Oct. 2010
Classification: FCT - PTDC/PSI/67381/2006

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Project name: Open Micro-Bio - A framework for computational simulation of cellular communities during BioProcess Engineering

Project leader within ISR: Prof. Agostinho Rosa (ISR/IST)

Project Description: This project is devoted to the development of **High-End modelling strategies** to describe the **Saccharomyces colony dynamics** based on **individual cell models** (ICM), using complex systems approaches. It is a software framework to simulate bioprocess engineering from the **microscale to the macroscale** levels, enabling to simulate biotechnological processes with great detail. The software framework is to be designed to simulate both colony dynamics under several scenarios, such as, production inside bio-reactors and growth in fermented foods, where the colony is highly affected by external factors such as fluid dynamics, chemical and biochemical reactions, nutrient diffusion and electromagnetic fields.

Open Source Bioinformatics

The large computational power necessary and model complexity, requires to use the latest legacy computational technology, both hardware and software; as well as programming and system development technologies, such as the use of GPU workstations and GRID computing. The project is **Open Source**! We hope to collaborate with you soon.

OpenMicroBio Microscale Apparatus

The project uses also the latest legacy technology in experimental apparatus. Experiments will comprise the use of batch/continuous bio-reactors, filming cellular growth and interactions at the microscope, using spectroscopy for determining nutrient diffusion and chemical/biochemical reactions. Furthermore, this project will use the latest developments in technometry for data analysis, in order to interpret and develop the individual cell models and 'emergent' microscale-to-macroscale cellular automata models.

People Involved

The project will involve highly qualified theoretical programmers and systems engineers, as well as experimental scientists; all from **CBMA-UM** (Molecular and Environmental Biology Research Center) **CEB-UM** (Centre of Biological Engineering – University of Minho) and **LaSEEB-ISR** (Laboratory of Evolutionary Systems and Biomedical Engineering Lab – Institute of Systems and Robotics, Lisbon).

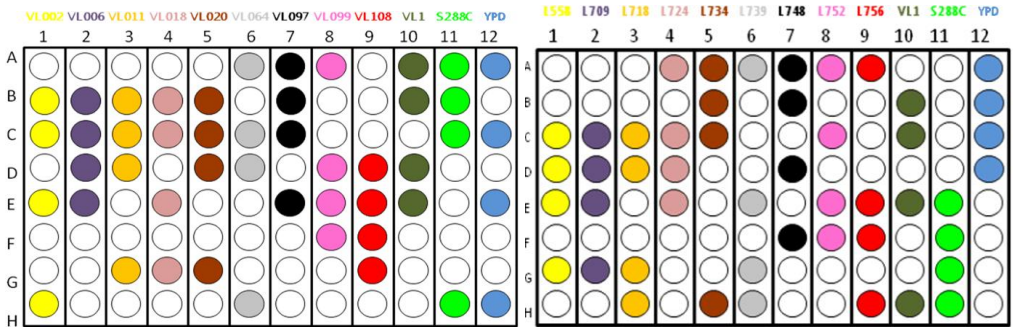

Fig.1 - Disposition of yeast strains in microplates

Task: GPU implementation of an Agent Simulation Framework

Agent-Based Modeling (ABM) is a methodology used to model complex dynamic systems, such as stock markets, societies and biological systems, which are difficult to model analytically using partial differential equations. This is particularly the case where the system consists of autonomous entities who can independently act based on their goals and evolve over time. The properties of the system as a whole emerge from micro-scale interactions between entities and the environment. Such is the case of biological systems at the cellular level, where ABM provides a way to represent the true diversity of existing entities and related non-linear interactions. ABM also allows the possibility of determining behavioral distribution (not just the average) and rapid insertion/removal of entities and interactions. ABM formalism frameworks now provide the necessary structural and organizational context present in differential equation modeling.

There are two main problems with ABM: a) it requires considerable computational power to simulate individual entities; and b) parameter tuning is not trivial. The last problem can be minimized with computationally intensive parameter sweeping techniques; as such, both problems fall in the category of hefty computational requirements. This issue arises because population size is extremely important in ABM. By nature, system level behaviors change with population size. In the case of the OpenMicroBio project populations in the order of millions of individuals are required to perform realistic simulations. Current

generation ABM frameworks such as Repast, NetLogo and MASON, do not scale well for populations larger than a few thousand individuals. This is because of the serial nature of computing on the CPU.

OpenMicroBio aims to utilize the computational capabilities of the Graphics Processing Unit (GPU) to speed up large-scale ABM simulations of yeast colony and biofilm dynamic behavior. There are two factors that enable the scale and speed of ABMs that we want to achieve: a) computing power, and b) memory bandwidth. The latest generation NVIDIA GeForce GTX295 is rated at 1.788 teraflops, with a cost of approximately 500€. The top rated Intel 6-core Xeon (costing about 3.000€) has a peak performance of 63.84 gigaflops. Memory bandwidth of the GPU is also superior to that of the CPU: approximately an order of magnitude higher for the given example. However, to make full use of the available computing power and bandwidth, computation has to be restricted to the GPU, with minimal or no communication with the CPU; this is because GPU-CPU communication through the PCI Express bus is very slow when compared to data transfer within a single chip die. Add the fact that GPU computation is much more limited in scope that its CPU counterpart, and it is possible to conclude that the development of GPU-ABM simulations is a non-trivial task.

The GPU is what is called a stream processor, i.e. a processor which can operate in parallel by running a single kernel on many records in a stream at once. A stream is simply a set of records that require similar computation. Kernels are the functions that are applied to each element in the stream. Since GPUs process records independently there is no way to have shared or static data. For each element we can only read from the input, perform operations on it, and write to the output. It is permissible to have multiple inputs and multiple outputs, but never a piece of memory that is both readable and writable. Thus, efficient GPU applications should have large data sets, high parallelism, and minimal dependency between data elements.

A common form of feeding data to the GPU is by using a 2D grid data structure; this process fits naturally with the GPU rendering architecture. Many computations naturally map into grids: matrix algebra, image processing, physics simulation or cellular automata (CA) execution. Since textures are used as memory, texture lookups can be used as memory reads. This allows certain operations, such as the map operation, to be performed automatically. The map operation simply applies the given function (the kernel) to every element in the stream.

Considering the previous arguments, it is possible to set an essential requirement for the development of an efficient ABM-GPU framework: it should be based on a 2D explicitly discrete simulation environment, where each discrete block is an independent processing unit. This approach adapts well to the GPU programming premise, but nonetheless limits our modeling options. Thus, it becomes imperative to determine if it is possible to develop the proposed yeast models within a framework with such constraints. In order to perform such verification, we developed a prototype simulator which allows the development of models within the set limitations.

Current results: LAIS 2.0

The prototype simulator, codenamed LAIS, runs on the CPU. However, LAIS emulates the constraints imposed by running simulations on the GPU: each block of 2D simulation environment is independent and can run in its own thread (fig. 1). The simulator is programmed in Java and uses scheduling and graphing tools from the Repast Agent Toolkit for rapid application development. Now on version 2.0 it extends the Repast AT into Repast Simphony and Metawidget, extends paradigm to use 3D, also paradigm to build models using GUI instead of direct XML.

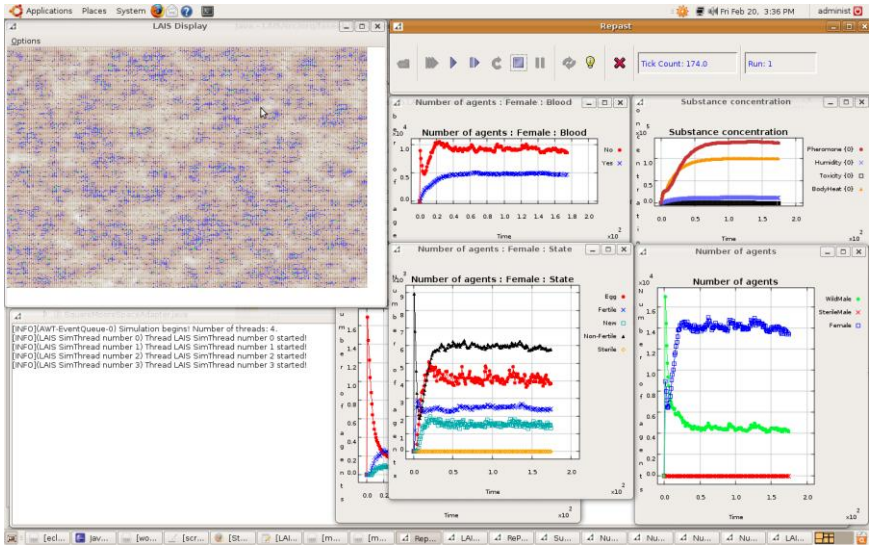

Fig. 2 – The LAIS 2.0 simulator

As required in general-purpose GPU computation (GPGPU), models developed on LAIS are discrete in space and time. Simulation space is divided in two layers. The lower layer, a specialized CA, is responsible for **substance** diffusion, reaction and degradation, while the upper layer represents the space where **agents** move and act. Communication between the two layers occurs when agents produce or consume substances, or when an agent action depends on the underlying substances. Substance concentration is real valued, and can be present in the lower layer of the model, or on the surface of agents. Substances are defined by bit strings. Agents communicate and act depending on the interaction of substances on the cellular surface and on the environment. Agents can present different substances at different times, contributing to a dynamic global behavior.

Confocal Laser Scanning Microscopy current development:

Confocal Laser Scanning Microscopy (CLSM) has been an important tool in the life sciences. Its success results in large measure from the fact that it allows in-vivo recording of the spatial distribution of fluorescence-tagged molecular complexes within a thin section of the cell, virtually removing the out-of-focus blurring present in wide field fluorescence microscopy images. Taking advantage of the highly reduced blurring, CLSM image analysis is widely used in the life sciences, especially in applications requiring local quantification of fluorescence-tagged macromolecule amounts where image segmentation plays an important role.

CLSM image-based quantification methodologies may range from the simple analysis of expression levels to more complex methodologies, such as Fluorescence Recovery After Photobleaching (FRAP), which allows in-vivo characterization of the molecular mobility. For many applications image segmentation, i.e. the identification of similar regions on an image, is an important step, not only to identify regions of interest but also to identify the regions that allow the characterization and compensation of undesirable phenomena such as photobleaching or the presence of a bias field.

Although it can be achieved by manually labelling the images, it can easily become a overburdening and difficult task on CLSM images showing complex cellular structures such as microtubules in the cytoplasm or high multiplicity of features such as transcription sites on virus-infected nuclei. Also, in many applications, CLSM image segmentation is a highly repetitive task possibly integrated in a more complex analysis procedure. In general, as more demanding or repetitive experimental procedures are adopted, manual image segmentation becomes increasingly overburdening and inefficient, motivating a growing interest on unsupervised CLSM image segmentation procedures.

We consider the case where a CLSM image is to be decomposed into a number of regions according to their fluorescence levels. Each region shows a regular fluorescence distribution pattern that results from both the statistical nature of the acquisition process and the more or less random distribution of the fluorescent probes. Naturally, the presence of highly scattered patterns becomes more significant with the use of high zoom factors or when the probe amounts are kept deliberately low, which is common in fluorescence quantification applications to ensure that virtually all probes are bound to the target macromolecule.

Statistical segmentation methods are therefore natural candidates for unsupervised CLSM image segmentation. One popular approach follows a Bayesian formulation and uses a maximum a-posteriori (MAP) paradigm to classify each image pixel in an image Y as belonging to one of K classes described by an associated model. To encourage neighbouring pixels to assume the same value and thus form large regions the underlying classification pattern X is described by a prior P(X). Unlike alternative methods, such as template matching or contour fitting, this approach has the advantage of not requiring prior knowledge on the number and shape of the image *objects*, being concerned only with the detection of statistically meaningful regions that may be combined afterwards according to some criteria to identify and classify the actual *objects*. Its performance is however limited by the ability of the intensity model $P_k(y) = P(y|x=k)$ to describe the data we are trying to identify. The model reflects our prior knowledge on the structure of the data and, independently on its accuracy, the segmentation method will try to identify features obeying its description. It is therefore critical that the model is able to describe the nature of the data as close as possible.

At the time of this work, it was informally accepted that, due to the photon-counting nature of the acquisition process, the intensity statistics should follow the Poisson distribution. That, however, only describes part of the image formation process. In fact the single parameter Poisson distribution shows poor performance describing CLSM image class data (see Fig. 3 - right). This has motivated the use of the Normal distribution for CLSM segmentation even though without any support besides the experimental observation that it reasonably describes high intensity regions. To obtain an improved model we used the CLSM image formation mechanics to derive a statistical model. As shown in Fig. 3 the model, which can be regarded as a linear mixture of background and fluorescence signals, closely follows the experimental data and unifies the description of high intensity classes, low intensity classes and background without the need of model selection mechanisms. Its performance was studied using criteria such as fitting error and model selection (AIC, MDL and MAP) and by its application to segmentation by a previously reported segmentation methodology based on Iterated Conditional Modes (ICM) (see Fig. 4).

The results were published on IEEE Transactions on Image Processing.

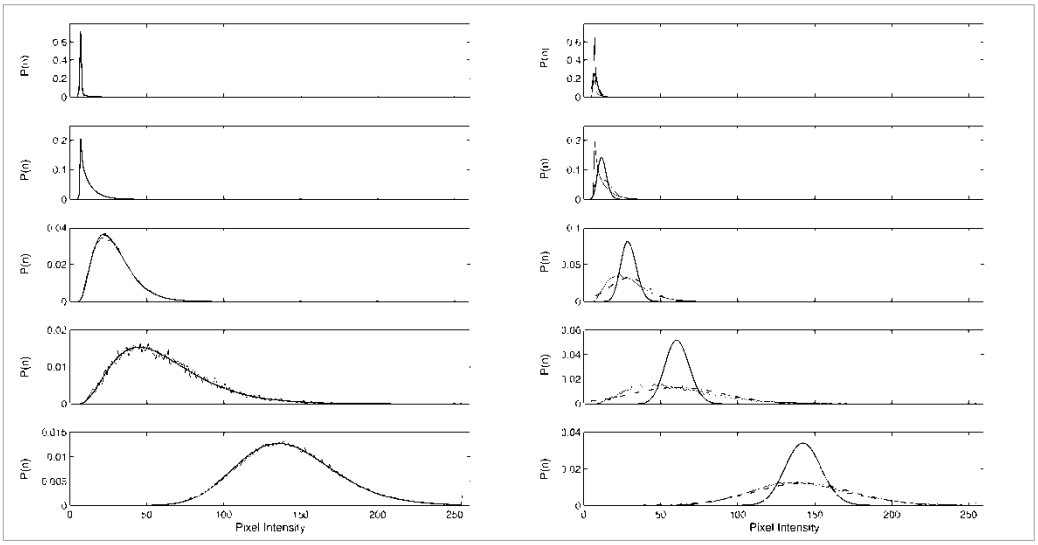

Fig. 3 - Fitting of experimental CLSM data using the proposed mixture model (left) and the alternatives (right). In both plots the thin line is the probability distribution of the experimental data (normalized histogram.The thick line on the left is the best fit with the mixture model obtained by an EM estimation method. The thick line on the right is the fitting by the Poisson model (continuous) and the Normal model (dashed)

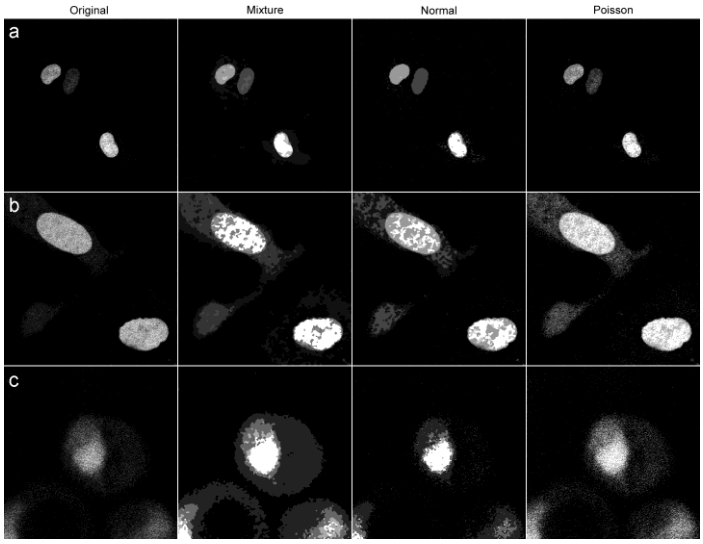

Fig. 4 - Segmentation results of He-La (first two rows) and Yeast (last row) cells using the TS-ICM algorithm and the Mixture, Normal and Poisson models.

Research Areas: BioSystem Modelling and optimization
Laboratories: Evolutionary Systems and Biomedical Engineering Lab (LaSEEB)
Project partners: Instituto Superior Técnico (IST), Universidde do Minho (UM)
Initiated: 2007
Expected Conclusion: 2010
Classification: FCT PDCTE/BIO/69310/2006

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Project name: Neuroimaging investigation of learning mechanisms in the human brain: new methodological approaches
Project leader within ISR: Prof. Patrícia Figueiredo (IST/ISR)

Research Areas: Neuroimaging; Biomedical Engineering.
Project partners: Instituto Superior Técnico da Universidade Técnica de Lisboa (IST/UTL), Faculdade de Ciências da Universidade de Lisboa (FC/UL)
Laboratories: Laseeb and SIPG
Initiated: Jan. 2008
Expected conclusion: Jun. 2011
Classification: PTDC-SAU-BEB-65977-2006

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Project name: Noninvasive Dynamic Neuroimaging in Epilepsy

Project leader within ISR: Prof. Patrícia Figueiredo (IST/ISR)

Research Areas: Neuroimaging; Biomedical Engineering.
Project partners: Instituto Superior Técnico da Universidade Técnica de Lisboa (IST/UTL), Faculdade de Ciências da Universidade de Lisboa (FC/UL), University College London (UCL).
Laboratories: Laseeb and SIPG
Initiated: Jan. 2011
Expected conclusion: Dec. 2013
Classification: FCT PTDC/SAU-ENB/112294/2009

2.2 POST-DOCS ACTIVITIES REPORT

2.2.1 Activity Report of Alessandro Saccon

Period: January until December 2010

Fellowship: IST/ISR

Description of activities: We have extended the theory of the projection operator approach for the optimization of trajectory functionalsfor nonlinear systems evolving on Lie groups. This has required the introduction of a geometricderivative notion for the repeated differentiation of a mapping between two Liegroups, endowed with affine connections. With this tool, chain rule like formulas where used to develop expressions for the basic objects needed for trajectoryoptimization.

We are interested in studying systems whose state space is the Special Euclidean group SE(3) or its tangent bundle T SE(3). The group SE(3) naturallydescribes the configuration manifold of aerial and underwater vehicles. One ofthe goal of the research is to use optimal control techniques to invert the dynamics of a given underwater vehicle (i.e., to obtain a state and control trajectorypair given a desired task specification) and to compute minimum energy trajectories to perform sea floor exploration missions, including obstacle and collisionavoidance.

We have also studied different ways to extend the Linear Quadratic Regulator problem to Lie groups. We are creating a set of test cases for which anexplicit solution is known to be used as test bench for the optimization strategy on Lie group. ThePontryagin's Maximum Principle has been usedto derive the necessary conditions for optimality and associated Hamiltonianequations. For a special class of systems and weighting costs defined on theSpecial Orthogonal group SO(3), we have found that the optimal feedback canbe computed explicitly and proven that the non-differentiable value functionwe obtain is the viscosity solution of an appropriate Hamilton-Jacobi-Bellmanequation on SO(3).

We have also investigated the numerical performance of different integrationschemes for the integration of the dynamics of a rigid body in a potential field.

2.2.2 Activity Report of Danesh Tarapore

Period: February – December 2010
Fellowship: FCT Project - "From Bio-inspired to Institutional inspired Collective Robotics" (BioInstBots)

Description of activities:
Simulation of the cell populations
The work on the project "From Bio-inspired to institutionally inspired Collective Robotics" began with a study on one of the biological system we are working on: the collective of T helper (Th) cells in the vertebrate immune system. The study involved developing an agent based simulation of the collective dynamics of regulatory and effector helper cells interacting with antigen presenting cells. While the effector cells help in fighting infection, regulatory cells serve to control the number of effectors in order to prevent auto-immune diseases. The simulation results were compared with differential equation results of the Cross Regulation Model obtained before. This work served as a stepping stone to the more complex simulations I then implemented on the collective dynamics of populations (macro level) of Th cells with complex internal gene regulatory network (micro level). In these simulations, each of the agents is endowed with a detailed gene regulatory network that controls the actions of the cells/agents depending interactions they make. Each agent (Th cell) is also characterised by its growth stage and its conjugation status to the antigen presenting cells.

Consequent to the coupling of the genetic regulatory network of many cells in a collective, the inner state of a individual cell constrains the collective state, and the collective state constrains the individual state of each cell. This simulator will allow to clarify the nature of these constraints and characterise the mechanisms involved in this multicellular system.

Immunology inspired collective robotics

The next phase of the project involved improving the current algorithms used to control collective robotic systems, while taking inspiration from the Th cell population. The work started with a thorough literature review on the subject. We then developed a spatial simulation of a Th cell population, where each cell is meant to represent a robot. Cell proliferation is simulated by the transfer of a controller from a "proliferating" robot to a "free" one. We are currently calibrating the simulation parameter to a task involving novelty detection of specific visual features in a foraging environment. The underlying controller of individual robots is based on the theory of self non-self discrimination by the immune system, utilizing the cross regulation model. With this approach, we intend to allow for a discrimination between sets of features without any centralized list.

Institutional inspired collective robotics

In parallel with the above mentioned studies, we began an investigation on the institutional economics approach to modelling collective robotic systems. The line of work began with a thorough review on institutional economy. This study has allowed us to understand the key differences between traditional and institutional economics. In addition we are in the process of highlighting the possible advantages of using an institutional approach instead of a purely self-organized system. We are also currently working on developing collective robotic experiments in simulation which are focussed on utilizing the important characteristics of institutional economics, namely incomplete information, bounded rationality and autonomy as well as the power of mediated interactions.

2.2.3 Activity Report of Jacinto Nascimento

Period: January - December 2010
Fellowship: My post-doctoral research is taking place at ISR, funded by FCT (with the scholarship PTDC/EEA-CRO/103462/2008). During this year my work is related with above research projects. Next I will summarize the contents of the project as well as the publications in this period.

Description of Activities:
My research activity during the year 2010 is framed in the context of two FCT projects: HEARTRACK and ARGUS.

HERTRACK – The initial phase of this project was to collect Ultrasound images of the left ventricle, as well as, the annotations given by the cardiologists. This task was done in collaboration with cardiology services of the Hospital Fernando Fonseca (Amadora-Sintra). During this task, 15 sequences of different patients were collected, each one suffering from a particular pathology. We also collected, the manual contours provided by Dr. Antonio Freitas and by three others specialists from his team. With these expert annotations, a comparison between the ground truth and the output of the algorithm to be developed is possible.

The following step was to develop an algorithm capable to detect and segment the boundary of the left ventricle. To accomplish this, we proposed a new pattern recognition model based on deep learning architectures for the automatic segmentation of the left ventricle of the heart in ultrasound images. Our model addresses the following problems inherent to pattern recognition approaches: 1) the need of a large set

of training images, 2) robustness to imaging conditions not present in the training data, and 3) complex search process, namely the gradient and the hessian (see [11,12]). At the present moment we have a journal version of the technical report [12] submitted to the IEEE Trans. Image processing.

Since the left ventricle exhibits sudden shapes changes with significant contour variability, in the systole and diastole of the cardiac phase, we studied the application of dynamical motion models able to cope with dynamic shape changes (see [1,8,10]). This was applied to lip sequences, since the lip boundary also exhibits a high dynamic range. The results of this application can be seen in [10].
From the study we observed that the run-time complexity of the search process, required to compute the first and second order optimization problems, is time consuming, leading to a high computational cost. We believe that computing these operations in a manifold, will lead to a drastic reduction of the search process. Thus, a manifold learning algorithm, capable of describing the motion of the heart has been studied recently, the so called Gaussian Processes Multiple Local Models (GP-MLM) [7]. Further work will comprise the integration of the GP-MLM with a pattern recognition model, and figure out if these two techniques are useful to detect and segment of the left ventricle in ultrasound data in a low dimensional space..

ARGUS - In this project we initially studied the application of non-parametric models to classify human trajectories. The basic assumption is that the human trajectories are modeled by a set of motion vector fields, each tailored to describe a specific motion regime. Trajectories are modeled as being composed of segments corresponding to different motion regimes, each generated by one of the underlying motion fields. Switching among the motion fields follows a probabilistic mechanism, described by a field of stochastic matrices. This work has been published in [5], where the classification of pedestrian's trajectories is performed, in scenario where the pedestrians are isolated.

To address the model selection question (how many fields to use?), we adopt a discriminative criterion based on classification accuracy on a held out set. Experiments with real data are shown in [6] which illustrate the ability of the proposed approach to classify complex trajectories into high level classes.

Further work in this area will comprise more complex scenarios, including interactions among pedestrians, and how to classify them using both non-parametric and parametric vector fields.

Another direction is to study other algorithms for model selection. Although, in [6] a method has been proposed, it leads to a prohibitive computational cost, since it relies on cross-validation. Indeed, is possible to use cross-validation for simple searches over model size, *e.g.*, if the search is restricted to a single parameter that controls the complexity of the model, the same cannot be said for more general searches over many parameters in which cross-validation is computationally prohibitive. We will study alternatives capable to cope with this issue avoiding an undesirable computational burden.

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2.2.4 Activity Report of Pedro Batista

Period: July until December 2010

Fellowship: IST, TRIDENT

Description of activities: This report refers to the activities carried out during 2010 by Doctor Pedro Batista, who currently holds a Post-Doctoral position at Instituto Superior Técnico / Institute for Systems and Robotics. After the defence of the thesis, Doctor Pedro Batista has continued to carry out research in the areas of navigation and control of autonomous vehicles, taking advantage of the large body of knowledge and insight that were obtained during his PhD.

The work developed by Doctor Pedro Batista focused on the problems of sensor-based navigation and control of autonomous vehicles and is divided in three parts. Namely, the estimation of linear motion quantities (position, linear velocities, and linear accelerations), in 3-D, of autonomous vehicles. Novel sensor-based navigation solutions were derived resorting to different sensors, in particular, position sensors, both in body-fixed and inertial coordinates, single range measurements, and multiple range measurements. The second part of the work, focuses on the attitude estimation problem. A novel sensor-based general framework was devised and exploited with different sensing devices. Finally, a new sensor-based integrated guidance and control strategies for homing of AUVs to a base station using an Ultra-short Baseline positioning sensor. The solutions proposed by Doctor Pedro Batista are deeply focused on asymptotic stability and performance properties and are strongly rooted on well known linear and nonlinear system theory, in particular Lyapunov and input-to-state stability concepts, backstepping techniques, and Kalman and H∞ filtering.

2.2.5 Activity Report of Porfírio Silva

Period: January – December 2010

Fellowship: FCT SFRH/BPD/35862/2007

Description of Activities: The research of this postdoctoral grantee is part of the IRS Group's efforts on Human-Robot Interaction. It is directed at developing Institutional Robotics, which is a new strategy to conceptualize multi-robot systems taking institutions as the main tool of social life of robots with bounded rationality and bounded autonomy. 2010 activities have been mainly directed to contributing to the "BioInstBots" FCT Project, within which project the grantee was responsible for one task.

Conceptual development is one of the main tasks of this grantee's research: importing concepts from Institutional Economics (and other fields of social sciences) that are expected to be useful in developing Institutional Robotics. Pursuing this trail, in 2010 the grantee produced (as part of the FCT project above mentioned) a report on "institutional economics for institutional robotics"; published two articles in national journals on the institutional approach and economics; and spent three months as a visiting researcher at the Facultad de Filosofía at Universidad Complutense de Madrid, developing conceptually the institutional approach.

Other main task of this grantee is to contribute to the progressive establishment, within the ISR Group, of a group of people interested and able to develop robotic experiments on Institutional Robotics. One aspect of this task is to create skills for working with the specific robots (e-pucks) that have been chosen to undertake experiments with multiple robots (ten or more) with institutional concepts. On this direction, the post-doc grantee has been the advisor for a BII grantee during 2010. He also started co-operating (as an external expert) with the advisor for a master student preparing his final dissertation's experimental work. On another level, the post-doc grantee has collaborated with some research activities of a doctoral student researching institutional robotics and swarmrobotics (IST/EPFL PhD dual degree program), and participated in the experiment (with "institutional roles") that resulted in a publication in 2010.

2.2.6 Activity Report of Rita Cunha

Period: January – December 2010
Fellowship: ISR/IST

Description of activities: In 2010, my research activity focused on developing sensor-based methodologies for control of unmanned air vehicles. In particular, I addressed the problem of stabilizing to a desired equilibrium point an eye-in-hand system, which consists of a single camera mounted on a rigid body free to move on SE(3).

Computer vision has long been recognized as an extremely flexible means of sensing the environment and acquiring valuable information for feedback control. One of the main questions in vision-based control, which continues to challenge researchers, is the Field of View (FOV) problem. Although several recent papers address the problem explicitly, no definitive solution has been proposed. As described in [2], the FOV problem presents two challenges: the features should not leave the image boundaries and they should also not become occluded by the object on which they are marked. In view of this problem, the key challenge addressed in this work was to find a stabilizing feedback controller that is guaranteed to keep the features visible and simultaneously provide a formal characterization of the region of the attraction for the resulting closed-loop system. We proposed a novel vision-based controller that guarantees almost global attractivity of

the desired configuration defined in SE(3). The approach adopted borrows from the work of authors like Bullo and Murray [3], Chaturvedi, McClamroch, and Bernstein [4], Cunha, Silvestre, and Hespanha [5], Koditschek [6] and Malisoff, Krichman, and Sontag [7]. Within this framework, rigid body configurations are expressed in their natural space, as elements of SE(3), so as to avoid problems related to singularities or the so-called unwinding behaviour [8]. The control algorithm proposed relies on a two-stage controller based on the current and desired image coordinates and reconstructed orientation and depth ratio information that enforces necessary conditions for feature visibility throughout the closed-loop trajectories of the camera.

In contrast to most vision-based strategies, which only consider the problem of keeping the features inside the camera's FOV [9,10,11], the proposed method also takes into account the second type of feature loss, which is due to self-occlusions. To this end, the necessary conditions for visibility are defined so that the camera not only points towards the features, but also remains in front of them. In addition, although there is no absolute guarantee that all feature points remain visible, the likelihood of maintaining feature visibility is reinforced by ensuring that a predefined feature point, such as the features' centroid, is kept inside the FOV as it converges to the desired value. Finally, by proposing a vision-based controller that guarantees almost global attractivity of the desired configuration defined in SE(3), we are not confronted with the difficult problem of local minima intrinsic to image-based strategies, and therefore we can obtain a well defined region of attraction for the desired equilibrium point.

2.2.7 Activity Report of Usa Vilaipornsawai

Period: January – December 2010´
Fellowship: Project Underwater Acoustic Network (UAN)

Description of activities:

This document reports the work and activities that had been done in 2010. The objectives of work are:

1. Implement a Multi-Channel Equalization with either Linear Equalizer (LE) or Decision Feedback Equalizer (DFE), a combined passive Time reveral (pTR) with equalizer, and a combined Frequency Shift pTR (FSpTR) with equalizer, denoted as MC-E, pTR-E and FSpTR-E, respectively.
2. Compare the performance of the MC-E, pTR-E and FSpTR-E schemes.
3. Performance map for Pianosa UAN10 experiment site.
4. Prepare software package that can be easily used with mimimum parameter adjustment.
5. Participate in engineering test and sea trial conducted in the UAN project.
6. Process/document real experimental data.

The following work has been done:

1. Implement the pTR-E and FSpTR-E schemes. In FspTR scheme, a slot-based FSpTR processing is performed, where frequency shifts applied to the IRs can change over slots to compensate for geometry changes over time. The FSpTR output is the concatenation of slots of the processed signals. With different frequency shifts for consecutive slots, there are phase jumps in the FSpTR output. In this work, the phase jump problem and propose two correction methods are addressed so that a standard Phase Locked Loop (PLL) can be used for phase synchronization after the FspTR processing and a equalizer can be applied. The first method is based on the phase of the Q function. The other method is based on the phase of the frequency shifted pTR outputs, obtained as a byproduct in the FSpTR processing. The pTR-E and FSpTR-E schemes rely only on short training sequence at the beginning of transmission block for Doppler estimation/compensation, phase synchronization using PLL, symbol synchronization and adaptive LE/DFE. The performance of pTR-E and FSpTR-E schemes is evaluated using simulated data and the experimental data from RADAR07 sea trial, UAN Eng test March 2010 and UAN Sept. 2010 Pianosa sea trial.

2. Implement the joint MC-E and carrier phase compensation scheme. This scheme also requires only short training sequence for phase and symbol synchronizations, adaptive LE/DFE, and Doppler compensation. The performance of the MC-E is evaluated using simulated data and the data from RADAR07 sea trial, UAN Eng test March 2010 and UAN Sept. 2010 Pianosa sea trial.

3. Compare the performance of the pTR, pTR-E, FSpTR, FSpTR-E and MC-E schemes. The results show that by using an adaptive LE/DFE in conjunction with the pTR or FSpTR, a significant performance is obtained as compared to the plain pTR or FSpTR, respectively. With simulated data, in some cases, the FSpTR-E provides a performance gain with respect to the pTR-E. With RADAR07 data, however, both FSpTR-E and pTR-E provide a comparable performance. This may due to the fact that the adaptive DFE can also compensate for time-variance of underwater channels, similar to the FSpTR. Moreover, with higher complexity and longer tranining sequence, the MC-E outperforms the pTR-E and FSpTR-E. During this study, it was observed that for time-varying channels caused by a relative speed between source and receiver, the system may fail if the Doppler effect is not properly compensated.

4. Digitize the bathymetry of Pianosa sites from given images. With the digitized version of bathymetry, in order to generate the performance map for the UAN experiment site, implement a distributed programs to run the whole system, including 1. Transmssion (BPSK) signal with frame duration of 10s, 2. bellhop acoustic channel models, 3. pTR-E & FSpTR-E receiver. That can be distributed to multiple cores on multiple machines. Since in order to make a 3D (varying ranges and depths) performance map a dense simulator points of the whole system need to be done, there are more than 100 points to run so it need to distribute among the machines. The performance map is done for a carrier frequency of 25.6 kHz. The same procedure can be done for other frequencies. The results may be used to indicate which locations can provide good performance, though it has not yet been used/tested in a real experiment. Note that it is expected that an accuracy of bathymetry, sound speed profile, bottom properties, etc. used in the model will have an impact on the accuracy of the performance map.

5. Attend the Eng. Test at Ria Formosa Lagoon in March 2010 and at Pianosa island during Sept 2010. During the Pianosa experiment there was a real-time data processing to verify the correctness of transmitted data, and provide and indication of transmitted singal power. Some data has been processed using the developed schemes, pTR-E, FspTR-E and MC-E techniques.

Process/document real experiment data using pTR-E, FSpTR-E and MC-E. For the UAN Sept. 2010 sea trial, four BPSK modulated signals, C1-C4 signals were transmitted, each with different data rates and frequency bands. For C1-C3, with data rates of 600, 1200 and 2400 symb/s, respectively, all three techniques provide encouraging results, with error-free transmissions in most point-to-point cases for C1 and C2 signals. The MC-DFE provides a better performance than pTR-based techniques, but requires a longer training sequence and is more complex and more sensitive to synchronization problem. For C4 signals with data rate of 4800 symb/s and carrier frequency of 19.6 kHz, the performance of all equalizers is rather poor as compared to the C1-C3 signals due to low SNNR and temporal coherence.

2.3 THESES

In this section the Doctoral and Master theses concluded, or in progress, during 2010 at ISR-Lisbon are identified.

2.3.1 Theses Concluded during 2010

DOCTORAL THESES (8)

José Maria Vasconcelos, "Nonlinear Navigation System Design with Application to Autonomous Vehicles", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, January 2010.

Abstract: This thesis addresses the design of navigation systems for autonomous vehicles. The first main contribution is in the field of accurate position and attitude estimation using low-cost, low-power sensor units. A navigation system architecture with integration of advanced aiding information is proposed, based on a high accuracy, multirate inertial navigation system (INS), combined with an Extended Kalman Filter (EKF) for inertial sensor error compensation. The navigation system is designed to exploit i) a frequency domain characterization of the vehicle motion using gravitational observations, and advanced integration of vector measurements, and ii) the differential equations that describe the autonomous vehicle dynamics. These aiding sources are integrated directly in the EKF, enhancing attitude and position estimation, and compensating for the effects of inertial sensor non-idealities, such as noise and bias. The proposed navigation systems are validated for autonomous vehicles using a realistic model-scale helicopter simulator, and experimental data collected onboard the DELFIMx oceanic craft.

The second contribution is the design of simple yet effective multirate complementary Kalman filters for attitude and position determination. The stability of the filter stability is demonstrated, and performance properties are derived for operational conditions found some in oceanic and terrestrial applications.

The third contribution is in the design of nonlinear position and attitude observers, formulated in non-Euclidean spaces. Using Lyapunov theory results, stabilizing feedback laws are derived for the classical combination of inertial sensor units with landmark measurements, vector observations, and GPS readings. The proposed observers dynamics are a function of the sensor measurements and state estimates, allowing for the practical implementation of the algorithms. The stability and robustness of the derived solutions in the presence bias and noise in some inertial sensors is also demonstrated.

Keywords: Nonlinear observers, Lyapunov stability theory, Navigation systems, Kalman filters, Complementary filters, Autonomous vehicles

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Pedro Batista, "Sensor-based Navigation and Control of Autonomous Vehicles", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, January 2010.

Abstract: This thesis addresses the problems of sensor-based navigation and control ofautonomous vehicles. The first part of the thesis, entitled Sensor-based Linear MotionEstimation, is devoted to the estimation of linear motion quantities (position,linear velocities, and linear accelerations), in 3-D, of autonomous vehicles. Novelsensor-based navigation solutions are derived resorting to different sensors, in particular,position sensors, both in body-fixed and inertial coordinates, single rangemeasurements, and multiple range

measurements. The second part of the thesis, entitled Sensor-based Angular Motion Estimation, focuses on the attitude estimation problem. A novel sensor-based general framework is devised and exploited with different sensing devices. The third part of the thesis, entitled Sensor-based Control of Autonomous Underwater Vehicles (AUVs), presents new sensor-based integrated guidance and control strategies for homing of AUVs to a base station using an Ultra-short Baseline positioning sensor.The solutions proposed in the thesis are deeply focused on the critical asymptotic stability and performance properties and are strongly rooted on well known linearand nonlinear system theory, in particular Lyapunov and input-to-state stability concepts, back stepping techniques, and Kalman and H1 filtering.

Keywords: sensor-based navigation; sensor-based control; linear motion estimation; attitude estimation; homing; autonomous vehicles

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Alex Alcocer Penas, "Positioning and Navigation Systems for Robotic Underwater Vehicles", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, January 2010.

Abstract: This thesis addresses the problem of underwater navigation of robotic vehicles using acoustic positioning systems. Several estimation problems are considered that are based on Range-Only measurements obtained from the Times of Arrival of acoustic signals. First, the Range-Only localization problem is addressed, which consists of determining the position of a vehicle given ranges to a set of landmarks with known locations. This problem arises in acoustic positioning systems such as GIB (GPS Intelligent Buoys). Several solutions based on Least Squares, Maximum Likelihood, and Extended Kalman filtering are presented and applied to real experimental data obtained during sea trials. Special attention is given to performance issues and practical problems related to acoustic positioning systems such as sound speed estimation and multipath mitigation.

Second, the problem of pose estimation with Range-Only measurements is addressed, in which the vehicle is equipped with an array of beacons with known relative position and uses range measurements to a set of Earth fixed landmarks. A Maximum Likelihood estimator is derived that requires solving a constrained min-imization problem on the Special Euclidean group SE(3). Borrowing tools from optimization on Riemannian manifolds, generalized gradient and Newton methods are derived to solve this problem. An alternative solution is derived in a system- theoretic setting by adopting a suitable Lyapunov function that is a function of range measurements only, yielding convergence conditions.

Finally, the thesis addresses the post-processing of acoustic positioning data. An extension of diffusion-based trajectory observers is derived that incorporates measurement error information.

Keywords: Underwater Navigation, Acoustic Positioning Systems, Range-Only measurements, Localization, Pose estimation, Maximum Likelihood estimation

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Nuno Pinho da Silva, "Robust Nonmetric Perception of Moving Rigid Bodies", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2010.

Abstract: Perceiving dynamic scenes of rigid bodies, through affine projections of moving 3D point clouds, boils down to segmenting the rigid motion subspaces supported by the points' image trajectories, whether they are from rigid objects, or from rigid parts of articulated objects. This work proposes a two-stage approach built upon formulating the problem as constrained subspace segmentation. The first stage is a robust linear subspace segmentation method, called the Grassmannian Maximum Consensus (GMC). We prove the existence of the Smooth Maximum Consensus (SMC) map, allowing the GMC to intrinsically search the Grassmann manifold for the maximum consensus subspace. It segments the subspaces underlying the features' trajectories from rigid motion, and explicitly rejects outlying representations, while accounting for possible motion degeneracies in a recursive fashion. Robustness is tightly coupled with recognizing degenerated motions because outliers may dwell in the dimensional slack. The second stage constraints the GMC 's geometric solution by imposing the number of rigid bodies and agglomerating the linear subspaces into their rigid segmentation. For a physically meaningful interpretation, the clusters must be consistent with the geometry of the underlying subspaces. However, most existing subspace measures are geometrically inconsistent, or ambiguous, motivating the construction of the Normalize Subspace Inclusion (NSI) criterion. Subspace (dis)similarities must be geometrically consistent with the orthogonal and inclusion relationship of the subspaces, thus being nonmetric. Overall, the approach is suboptimal, because the GMC's geometric solution depends on the initialization. However, it overrides the potential exponential complexity of randomly sample a representative number of models, for each admissible subspace dimension, by shooting a geodesic from the model underlying the (minimal subset of) nearest neighbors with the highest SMC score, thus exploring the global character of the maximum consensus criterion. Furthermore, it is intrinsically robust and accounts for motion, or shape, degeneracies. The approach is evaluated on real data, and compared with state-of-the-art methods, showing its potential in perceiving moving rigid bodies, and leveraging the results for challenging outdoor scenes and when the number of moving bodies is higher than two.

Keywords: Robust Rigid Motion Segmentation, Geometric Optimization, Subspace Similarities.

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Ricardo Ferreira, "Reconstruction of Isometrically Embedded Flat Surfaces From Scaled Orthographic Image Data", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2010.

Abstract: In this thesis a method to reconstruct a class of non-rigid surfaces from image point features is presented. The class of surfaces to which it applies consists of flat surfaces isometrically and smoothly embedded in Euclidean three-space of which the model example is a smoothly bent sheet of paper observed in different configurations. Here it is proposed to recover: 1) the feature locations of the flattened surface as well; 2) the three-dimensional pose of the surface in each image. The cameras are considered to be scaled orthographic and they are not assumed to be previously calibrated. It is assumed that the features have been previously matched between images but occlusions are allowed. Due to the complexity of representing isometric functions it is not possible to describe a simple cost function and assume that there's an optimization

algorithm that solves it. Instead, the problem is split into subproblems, where each step refines the previously obtained solution. The first subproblems deal with finding a discrete solution for the problem, i.e. one where only the feature points are considered. The last step provides a bridge that allows for the whole continuous embedded surface to be considered. The solution depends heavily on certain non-mainstream matrices, here denoted as "sub-Stiefel". These matrices are of great importance when considering orthographic and scaled orthographic cameras, but no literature describing them has been found so far. Here, these matrices are characterized and described in depth.

Keywords: Computer Vision, 3D Reconstruction, Non Rigid Reconstruction, Structure From Motion, Isometric Embeddings, Non Linear Optimization.

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Hugo Costelha, "Robotic Tasks Modelling and Analysis Based on Discrete Event Systems", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2010.

Abstract: This thesis introduces a Petri net (PN) based robot task modeling framework. In the models, PN places represent actions, tasks, and predicates set by sensor readings and communicated messages, while transitions represent events. The proposed framework follows a structured hierarchical approach ranging from the environment models to the task plan models. These models can be used both for task execution and analysis. The PN based task plan can be executed directly in the robots. For analysis, all the models are composed into a single PN which is analyzed both for logical and (probabilistic) performance properties. Both stationary and transient properties are analyzed. Environment models include uncontrollable events which model the world physics and/or other agents impact on the world. Observation models allow determining the impact of observation failures in the task performance. The introduction of communication models, either using explicit (e.g., wireless) or implicit (e.g., vision-based observation of team- mates), allows modeling and analysis of multi-robot tasks involving the coordination of two or more robots. An identification method is proposed, which allows creating environment and action models from real data. Results illustrating the methodology are presented for a robotic soccer scenario using a realistic simulator.

Keywords: Robot Tasks, Petri Nets, Modelling, Analysis, Identification, Execution

Members of the thesis committee:
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Gonçalo Neto, "Planning, Learning and Control Under Uncertainty Based on Discrete Event Systems and Reinforcement Learning", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: There is a growing interest in models that combine planning, control and learning for decision making. The goal of these hybrid methods is to retain character- istics from the different approaches: the deliberative nature of pre-programmed plans, the reactive nature of control policies, and the adaptive nature of learning to be able to tackle uncertainty.

In this work we choose Discrete Event Systems, and particularly Stochastic Time Automata, as the basis for modeling, tackling problems where the changes in the state are driven by the occurrence of events. For this reason, we work in continuous time since the occurrence of these events does not generally show temporal periodicity.

We use Supervisory Control as an offline planning approach to specify the behaviors that the agent is allowed to have, providing planning constraints rather than fixed pre- programmed plans. The control of the system is made by defining the firing probabilities of controllable events which are considered to fire immediately after the decision; this kind of events is, e.g., associated with starting or stopping actions in a robot. Reinforcement Learning is used to optimize the control policy, within the bounds defined by the supervisor.

Novel contributions of this work besides the modeling approach include definitions of full and partial observability for Stochastic Timed Automata (STA); derivation of the conditions on the parameters of the STA that ensure convergence of the reinforcement learning algorithm under several observability conditions; and the derivation of optimality equations under partial observability, discussion of the connection with Partially Observable Markov Decision Processes (POMDP) and extension of a generic POMDP method to work with our event-based system.

Simulation results are shown to illustrate the applicability of the presented method and the effects of partial observability.

Keywords: Discrete Event Systems; Stochastic Timed Automata; Supervisory Con- trol; Semi-Markov Decision Processes; Reinforcement Learning; Observability.

Members of the Thesis Committee:
Mário Figueiredo (IST)
Pedro U. Lima (IST, Advisor)
Nikos Vlassis (TU Crete)
Thibault Langlois (FCUL)
Luís Custódio (IST)
Francisco Melo (IST)

Nicolas Greggio, "Unsupervised Object Segmentation, Representation, and Tracking for Humanoid Robots", Ph.D. Thesis, Dec 2010

MASTER THESES (19)

Manuel Biscaia, "Supervisory Control of Petri Nets using Linear Temporal Logic", MSc. Thesis, Instituto Superior Técnico, DM, Lisbon, Portugal, January 2010.

Abstract: Given the need of automatic methods for analysis and synthesis of complex robotic tasks, we propose a method that allows a designer who uses Petri nets as representations of robotic tasks to enforce an event based specification upon a simpler Petri net, utilizing concepts from earlier works in Supervisory Control of discrete event systems. The specifications are given in QPLTL, a quantified linear temporal logic strictly more expressive than LTL. This formalism is close enough to our thought processes, allowing us to effectively reduce the time spent when designing a Petri net robotic task. Due to need of researching Petri nets ω-languages for our main line of work, we suggest an exte
and present one Petri net ω-language characterization theorem.

Keywords: Petri Nets, Supervisory Control, Linear Temporal Logic.

Members of the Thesis Committee:
M. Cristina Sernadas (IST)
Pedro U. Lima (IST, Advisor)
Paulo Mateus (IST)
Jaime Ramos (IST)

Tiago Veiga, "Cooperative Active Perception using POMDPs", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, May 2010.

Abstract: In this thesis we present a new approach to cooperative active perception problems in networked robotsystems. Our goal is to perform task planning in a context where multiple sensors of different kinds cooperatein order to successfully develop tasks, given the limitations in every kind of sensors.Cooperative active perception is the problem of active perception involving multiple sensors and multiplecooperating decision makers. Active perception means that an agent considers the effects of its actions onits sensors. Here, we consider the case in which a mobile sensor cooperates with a network of fixed sensors inorder to reduce uncertainty in the system.We propose a decision-theoretic approach to cooperative active perception. In particular, we propose Partially Observable Markov Decision Processes (POMDP) as the framework for such problems. POMDPs provide an elegant way to model problems of decision-making under uncertainty, offering a strong mathematicalbackground by explicitly modeling the imperfect sensing and actuation capabilities of the overall system. Dueto this capability, POMDP keep a track on the belief over states, allowing for feature tracking.We show how to model a cooperative active perception problem under the POMDP framework, and wepresent promising results in real scenarios. In particular we apply our model in a classifier system which is ableto reason, from several events detected in an environment, which are of interest, and classify them, provingthat our model actually applies in those kind of problems.

Keywords: Networked Robot System, Partially Observable Markov Decision Processes, Planning under Uncertainty, Cooperative Active Perception, Classifier System.

Members of the Thesis Committee:
Carlos Silvestre (IST)

Pedro U. Lima (IST, Advisor)
Matthijs Spaan (IST/ISR, Advisor)
Mário Figueiredo (IST)

Nuno Rodrigues, "Individual and Cooperative Behaviors Representation Based on Petri Nets", MSc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, October 2010.

Abstract: The objective of this thesis is to develop, test and analyse individual and cooperative behaviors within the framework of the SocRob project. These behaviors are modelled using Petri Nets where the places represent roles, behaviors, actions or predicates. The latter compose a world model using information collected by each robot sensors or from messages received from other robots. Events are represented by transitions.

Individual behaviors were introduced for situations that were not contemplated before, such as defensive behavior when the game is in a foul situation, dropped ball situation and search for the ball. Other behaviors were also optimized to increase the success rate when executed and to keep up with changes in the RoboCup Middle Size League rules. Regarding cooperative behaviors a new model for commitment was introduced that can be used in more situations than the ones described in this work (short pass, long pass).

Every behavior developed can be composed with models of the actions and the environment in order to obtain a single model in which a quantitative analysis can be performed by using Markov Chains. Environment models use not only events controllable by the robots, but also uncontrollable events that represent the world physics and/or the impact of other agents in the world. This is a simplified representation of the surrounding world, nevertheless important conclusions can be obtained concerning quantitative performance of the robot team.

All the developed behaviors were tested in the simulator (Webots) and the real robots.

Keywords: Petri Nets, Robotic Soccer, Individual Behavior, Relational Behaviors, Quantitative Analysis, Commitment Establishment.

Members of the Thesis Committee:
Carlos Silvestre (IST)
Pedro U. Lima (IST, Advisor)
Carlos Cardeira (IST)

João Pedro Trindade Caxias Ferreira, "Contactless Power Supply System for Transmission Line Inspection Robots", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, October 2010.

Abstract: High voltage transmission lines have nowadays an important role on the power network.Delivering electricity everywhere and with the best quality is the goal of all the electricitycompanies around the world. The premise of this work aims at develop an energyharvesting system to use on a robot, for inspection of high voltage overhead power lines.The power supply operating principle is to obtain energy from the magnetic energyaround the power supply line by clamping a transformer around the line, and transform it to DC power supply for the robot.Full autonomy is the key factor when assessing the economical advantages in use robotswith such functions. Monitoring the power lines network during long periods and longdistances will permit to increase the power network quality, by reporting the lines problems.

This project innovates with a new power supply system for the robot by usingthe magnetic energy around the power supply lines. This energy is obtained using aclamp-on cylindrical transformer which in turn will supply a power switching rectifierthat is controlled in such a way that the clamp-on transformer sees the switching rectifieras a time dependent resistor placed in the transformer secondary. This means that theThévenin equivalent of the robot power supply system, seen from the transformer, can be resumed as a resistance at each instant.It is assumed that the robot operates on power cables carrying currentsfrom nearly 100 A to roughly 1000 A. When transmission current drops below a certainlimit the robot hibernates and a signal is sent to operation central, and when it overlapsthe maximum the clamp-on transformer is opened to prevent damage to the robot.

Keywords: Power supply system, Transformer, Current power transformer, PWM rectifier, resistor emulating rectifier, AC/DC converter.

Members of the Thesis Committee:
João Palma (LNEC)
Fernando Alves da Silva (IST)
João Silva Sequeira (IST)

Carlos Martins, "Goalkeeper Robot Behavior Design and Coordination in Soccer Robotics", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, October 2010.

Abstract: In a robotic soccer team, one of the elements is the goalkeeper which has particular challenging character- istics, different from the other teammates, when designing and coordinating the execution of a robot task plan. Although, this player has a simple purpose, i.e., to defend the goal from the opponent kicks, it should exhibit a richer behavior with a perfect coordination between the different actions in order to have an important role in the team.

This thesis aims at developing and implementing a complete, tested and effective behavior for a goalkeeper of a robot soccer team, using an omnidirectional soccer robot hardware and Petri Nets to model task plans. The different primitive actions and behaviors as well as the events to switch between them were designed and implemented.

We also aim at modeling and analyzing, both qualitatively and quantitatively, the goalkeeper role in order to have a model-based knowledge of the task performance in different possible situations, such as different types of opponent teams. For this purpose, we use a modeling and analysis framework based on Generalized Stochastic Petri Nets and model the different components of the goalkeeper role, such as the environment, action and task models.

Keywords: Goalkeeper, Robotic Soccer, Robot Task, Petri Nets, Modelling, Analysis, Execution.

Members of the Thesis Committee:
Carlos Silvestre (IST)
Pedro U. Lima (IST, Advisor)
Carlos Cardeira (IST)

Andreia Catarina Costa Duarte, "Mobile Acquisition Platform for Sleep Assessment", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: Os distúrbios de sono afectam uma elevada percentagem da população mundial, estando frequentemente associados a outras patologias, o que sublinha a importância de diagnósticos precoces e correctos. Embora a polissonografia (PSG) seja o método de eleição neste tipo de diagnóstico, é um exame dispendioso, incómodo para o paciente e geralmente realizado em instalações clínicas, pelo que não é adequado para registos prolongados.

O objectivo desta tese é criar um sistema extremamente portátil, uma alternativa aos exames de diagnóstico existentes, baseada numa cinta cardíaca e num telemóvel, ligados por Bluetooth. Esta plataforma de aquisição móvel para diagnóstico de distúrbios de sono, designada MAPSA ("Mobile Acquisition Platform for Sleep Assessment"), é um sistema de utilização simples e intuitiva, que monitoriza algumas variáveis fisiológicas como o electrocardiograma, respiração, temperatura ou actigrafia. Adicionalmente, regista informação relacionada com o sono, através de diários de sono e de sonho. Ainda que este sistema adquira um conjunto de dados muito mais limitado, não interfere significativamente na rotina do paciente, o que permite a realização de registos prolongados e o diagnóstico de distúrbios não tão facilmente detectados pela PSG.

Ilustram-se exemplos de utilização e dos resultados que a plataforma devolve, mostrando as possibilidades que esta pode trazer tanto no diagnóstico de distúrbios de sono como noutros contextos - "biofeedback" na variabilidade cardíaca. A MAPSA utiliza componentes acessíveis e uma interface simples, vantagens relevantes na prática diária de especialistas do sono.

Keywords: Distúrbios de sono, Cinta Cardíaca, Telemóvel, Diário de Sono, Dirário de Sonho.

Ana Luísa Luis Coito, "Assessment of Obstructive Sleep Apnea Syndrome by Spectral Analysis of Physiological Parameters", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: Obstructive Sleep Apnea Syndrome (OSAS) is a very common sleep disorder that is associated with cardiovascular and neurocognitive impairments. The pathophysiological mechanisms underlying the morbidity of OSAS are not completely understood, which make the research on the OSAS an important issue.
In the current study, obstructive sleep apnea (OSA) episodes were carefully selected and segmented in three parts, the OSA event (dur) and a certain time period immediately preceding (pre) and following (post) the event in order to assess the dynamic electroencephalographic (EEG) power changes, in four frequency bands: delta (δ), theta (θ), alpha (α) and beta (β). Furthermore, Autonomic Nervous System (ANS) activity was assessed through the spectral analysis of heart rate variability (HRV) components in the three mentioned periods. For that purpose, continuous wavelet transform was the elected spectral analysis technique to present the results.
A new approach was carried out for assessing EEG power changes during an OSA episode: topographic EEG brain mapping. This technique was found to be a powerful tool to better visualize spectral changes during OSA episodes across the whole brain. The results demonstrate that there is a significant decrease in the EEG _ power during OSA, that is not totally recovered immediately after the episode. Since _ waves are linked to learning and synaptic plasticity processes, it is hypothesized that decreased _ power during OSA may contribute to the cognitive deterioration in patients with OSAS. The HRV analysis results show the presence of a pattern during OSA episodes, which is related to an impaired autonomic control of the heart in these patients.

Keywords Obstructive Sleep Apnea, Electroencephalogram, Heart Rate Variability, Spectral Analysis, Continuous Wavelet Transform, Brain Mapping.

Members of the Thesis Committee:
Prof. Fernando Lopes da Silva (IST)
Prof. João Sanches (IST)
Prof. Teresa Paiva (FML)
Prof. João Pedro Gomes (IST)

Ana Rita Mendes, "Planning under Uncertainty for Search and Rescue", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, November 2010.

Abstract: In this thesis an application of POMDPs (Partially Observable Markov Decision Processes) in a realistic search and rescue problem is presented. More specifically, the aim of the problem is to find victims in a disaster environment. In order to do so, the actions to execute in each time step must be carefully planned, and the uncertainties of the problem (for example, uncertainty regarding sensors or actuators) need to be taken into account. To deal with these uncertainties POMDPs will be used, a planning solution known from the literature. The main goal of this thesis is the definition, implementation and testing of a POMDP model that suits the problem and its characteristics. As such, a POMDP model is built from scratch. The environment and its features will be learned, by letting the robot interact randomly with the environment, allowing the transition probabilities to be learned and taken into account when building the POMDP model. The model is then tested and it can be concluded that POMDP based solutions, and this solution in particular, do work well in real problems.

Keywords: POMDPs, Search and Rescue, USARsim, planning.

Members of the Thesis Committee:
Carlos Silvestre (IST)
Pedro U. Lima (IST, Advisor)
Matthijs Spaan (IST/ISR, Advisor)
Franciso Melo (IST, INESC-ID)

Nuno Barros, "Liver Tumor Classification based on DCE-MRI Images", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: Dynamic Contrast Enhanced Magnetic Resonance Imaging has proven to be the most efficient diagnose method for liver tumor identification. This image technique allows assessing tissue perfusion by following the diffusion of an intravenous contrast agent in the human body. DCE-MRI imaging capabilities can be considerably increased by modeling the imaging data acquired with pharmokinetic models that describe the contrast diffusion process. The application of such models allows retrieving several perfusion parameters.
The liver is characterized by a dual-blood supply: 75% of the blood that enters the liver has its origin in the hepatic portal vein and the rest 25 % in the hepatic artery. However, this balance can be altered locally or globally in several pathological conditions, like for example in liver cancer. So, the main strategy used in this thesis to assess differences between liver tumors consisted in the measurement of the arterial ratio of tumor tissue. This implied the use of a dual-input liver perfusion model, where the hepatic perfusion is calculated based on the signals retrieved from the aorta and the portal vein.
The model was implemented in MATLAB and a Graphical User Interface was created. Six cases with confirmed diagnosis given by the hospital Erasme, in Brussels, were analyzed using the method described. These imaging

studies contained a total of 9 tumors, including 4 benign tumors and 5 carcinomas. The model used allowed collecting a considerable amount of perfusion parameters apart from the arterial ratio.
Besides using low temporal images, the method was able to detect clear differences between benign and malignant tumors in terms of the arterial ratio. The results confirmed the fact of liver carcinomas being mostly supplied by the hepatic artery. Benign tumors registered mean arterial ratios between 16.6% and 37.5%. On the contrary, malignant tumors revealed an arterial component in a range between 51.4% and 75.5%.

Keywords: Liver Neoplasms, Tumor Classification, Pharmacokinetics, DCE-MRI, Arterial Ratio.

Members of the Thesis Committee:
Prof. Paulo Freitas
Prof. João Sanches
Patrícia Figueiredo
Prof. Rui Tato Marinho

Teresa Inês Gonçalves Murta, "EEG-fMRI measures of functional brain connectivity in epilepsy", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: Effective connectivity is the influence that a neural system exerts over another, either at a synaptic or cortical level. The study of effective connectivity in epilepsy was performed using simultaneously recorded electroencephalography and functional magnetic resonance imaging (EEG-fMRI) data, with the aim of identifying the focus and propagation network involved in an epileptic seizure. Data from five focal epilepsy patients undergoing pre-surgical evaluation were analysed. Three approaches for the effective connectivity analysis were investigated: a method based on the General Linear Model (GLM) at different neurophysiology regressor lags (*LasgM*), a connectivity model-based method, Dynamic Causal Modelling (DCM), and a data-driven method, Granger Causality (GC). The concordance of the *LagsM* results with the clinical expectation suggests that this method can be useful as a complementary approach when investigating seizure propagation using EEG-fMRI data. DCM analysis provided meaningful and significant results in cases where a sufficient number of seizure events were recorded, but suffered from the generally poor signal-tonoise ratio (SNR) of the data. A simulation study was performed in order to establish the validity of the GC approach for the type of data and connectivity networks under investigation and the results showed that it is not appropriated to use in these cases. In summary, this work explored three different methodologies for studying effective connectivity in EEG-fMRI data of epileptic seizures and found that a simple GLM-based method may provide useful seizure focus and propagation information, while a DCM approach allows testing specific hypothesis when sufficient SNR is present in the data.

Keywords: DCM, Effective Connectivity, Epilepsy, GC, Seizure

Members of the Thesis Committee:
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Prof. Patrícia Figueiredo (IST)
Dr. Alberto Leal (Hospital Júlio de Matos, Lisboa)
Prof. Alexandre Andrade (FCUL)
Dr. Marta Garrido (UCL, UK)

João Pedro Forjaco Jorge, "Sources of signal fluctuations in fMRI at 7 Tesla", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: The development of high-field magnetic resonance imaging (MRI) systems has allowed for critical improvements in image signal-to-noise ratio (SNR), potentially leading to higher sensitivity and spatial resolution for functional MRI (fMRI) techniques. However, recent studies have shown that these potential advantages become significantly compromised by increased signal fluctuations arising from correlated noise sources, namely physiological processes. This work comprises the analysis of blood oxygenation level-dependent (BOLD) fMRI data acquired at 7 Tesla, using a standard 2D echo planar imaging (EPI) and a segmented 3D echo volumar imaging (EVI) technique, from healthy subjects at rest or submitted to a visual localizer (Loc) paradigm. A principal component analysis (PCA)-based approach and a physiological regressor (PR)-based approach were investigated for correlated noise correction. As expected, 3D data displayed significantly higher spatial SNR (sSNR) than 2D data, but comparable temporal SNR (tSNR); the information explained by general linear models (GLM) was similar in both cases, and 3D analyses exhibited lower sensitivity to neural activation. In general, both correction approaches produced significant increases in tSNR, explained information, and activation sensitivity for both acquisition techniques, but especially for segmented EVI. The PCA-based approach was the most effective correction method; however, the PR-based approach further allowed the characterization of the relative contributions of different noise sources, confirming significant relative increases in physiological noise from 2D to 3D acquisitions. In summary, although greater physiological noise contributions were found in segmented EVI data acquired at 7 Tesla, these were shown to be adequately compensated for by appropriate noise correction methods.

Keywords: functional magnetic resonance imaging, high-field imaging, signal fluctuations, physiological noise.

Members of the Thesis Committee:
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Dr. José Pedro Marques (CIBM/EPFL, Suiça)
Dra. Rita Nunes (FCUL)
Dr. Wietske van der Zwaag (CIBM/EPFL, Suiça)

Carlos Alberto Falé Cabral, "Classificação automática de estados cognitivos em fMRI", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

Abstract: Functional Magnetic Resonance Imaging has established itself as the most powerful technique available today to measure brain activity induced by a perceptual or cognitive state. The inverse problem is considered in this study; given the measured brain activity, our goal is to predict the perceptual state. Machine Learning algorithms were used to address this problem in this work. Multi-subject fMRI data analysis poses a great challenge for the machine learning paradigm, by its characteristics: the low Signal to Noise Ratio (SNR), high dimensionality, small number of examples and inter-subject variability. To address this problem, several methods of classification and feature selection were tested. The main criterion of feature selection was mutual information in a univariate method, but a multivariate feature selection was also proposed. Both a single classifier and an ensemble of classifiers were tested. The ensemble of classifiers approach consisted on training an optimized classifier for each class and then the combination was made. The data analysed was obtained from three multi-subject experiments of visual stimulation with 4 classes of stimuli, at different magnetic field strengths. The ensemble of classifiers performs best for most data sets and methods of feature selection. The multivariate method does not show overall improvement in the classification. In summary, the results suggest that a combination of classifiers can perform better than a single classifier, particularly when decoding stimuli associated with specific brain areas.

Keywords: Brain decoding, ensemble of classifiers, fMRI, machine learning, multivariate feature selection, retinotopic mapping, and visual localizer.

Members of the Thesis Committee:
Prof. Fernando Lopes da Silva (IST)
Prof. Patrícia Figueiredo (IST)
Prof. Margarida Silveira (IST)
Prof. Alexandre Bernardino (IST)

João Filipe Teles Ferreira, "Mobile robot fault-tolerant navigation in nuclear fusion scenarios of ITER", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, December 2010.

Abstract: This thesis proposes a localization system for mobile vehicles, without sensors on board, in indoor environments. The sensory part is a network composed by laser scanner sensors placed in defined points on the building. This system is useful in cases where sensor installation directly on the vehicle is not advised, due to his or his job characteristics.

An optimization method was developed to place the sensors on the building. Improving the network disposition on the building, the quality of gathered information increases. Using this information, two localization methods were developed and tested, one based on extended Kalman filter, and other on particle filter. Both were studied and compared, in simulation environment, concerning their performance and reliability. It was analyzed the impact of sensors disposition on the building in the localization system, evaluating the robustness to different sensor configurations, including a possible fail of some of them.

From the experimental results, the approach that suits better this application is the particle filter localization method, the resulting estimations have good precision, it is robust to sensor failure and, facing a general failure, like power failure, it manages a short time global localization. Although these conclusions are based on simulation, the method shows promising results for a future real application.

Keywords: Localization, Autonomous Mobile Vehicles, Sensor network, Laser scanners, Data Fusion.

Members of the Thesis Committee:
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Jorge Manuel Miranda Dias (Universidade de Coimbra)
Rodrigo Ventura (IST)
Alberto Vale (IPFN)

Carlos Rui Peres Palma Neves, "Metodologias para a Locomoção de Robots Humanóides", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, December 2010.

Abstract: The controlled locomotion of a legged robot presents several challenges, mainly due to the instability inherent to legged locomotion and to the fact of being very sensitive to slope changes and other obstacles. Complex sensory systems and demanding processing abilities are often required to maintain balance, that together with precise servo control leads to high energy consumption. This dissertation deals with some of these problems by creating a simple controller and implementing a learning system that allows a Bioloid Humanoid robot to adapt to different slopes while walking and maintaining its balance.

In order to reach this goal, a simulation of this robot in different platforms was developed in the Webots simulator and a Python controller was developed. The controller is centered around a quaternion based Extended Kalman Filter that uses the measurements of a six axis inertial measurement unit as inputs to perform an attitude estimation of the torso. Using this estimation, it is possible to create a controller to adjust to new ground slopes and change the walking gait. The walking gaits are defined in motion files and using interpolation it is possible to adapt gaits for different ground slopes.

Finally, a learning system was developed with the goal of improving the performance of the controller by identifying the ground slope without resorting to the position controller and therefore in- creasing the speed of the algorithm. Several simulations were run in Webots and the results presented show the success of the algorithm.

A Bioloid Comprehensive Kit has been purchased and the Humanoid model has been assembled and tested. This has allowed the creation of a better virtual model and will allow a future implementation of the developed controller on the robot.

Keywords: Humanoid robot, Legged Locomotion, Bioloid, Inverted Pendulum, Quaternions, Ex- tended Kalman Filter, Webots.

Members of the Thesis Committee:
Carlos Silvestre (IST)
Vítor M. Santos (Universidade de Aveiro)
Rodrigo Ventura (IST), Advisor
João Sequeira (IST), Co-Advisor

Guilherme Luís Morgado Soares Teixeira dos Santos, "Chromosome identification and pairing in optical microscopy images", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, December 2010.

Abstract: Cytogenetics plays a central role in the detection of chromosomal abnormalities and in the diagnosis of genetic diseases. A karyogram is an image representation of human chromosomes arranged in order of decreasing size and paired in 23 classes.

This thesis proposes novel approaches to improve the current automatic pairing algorithm's results: Increasing the quality of the feature set through the simplification of its extraction process; implementing and testing a new supervised pairing algorithm (ASLCD) and its integration with an existing one (CaLCD). Using a set of geometric and band pattern features extracted from the chromosome images, the algorithms generate distance matrices between them, which are then used to determine the optimal pairing. For the CaLCD algorithm, the pairing is improved by the use of a rough SVM classification.

Two datasets with contrasting quality levels were used to test and validate the algorithms. Relevant improvements were obtained, with mean pairing rates above 81% for the lowest quality dataset, while for the highest quality dataset, mean pairing rates above 94% were reached – close to the rates obtained by human operators.

Keywords: Pairing, Chromosomes, Features, Classifiers, Karyotyping, Optical Microscopy.

Members of the Thesis Committee:
Carlos Silvestre (IST)
Ana Maria Rodrigues de Sousa Faria de Mendonça (Universidade do Porto)

João Sanches (IST)
Rodrigo Ventura (IST)

Marco Filipe Pinto Leite, "Estimation of the haemodynamic response to epileptic activity in EEG-fMRI data", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2010.

Abstract: Electroencephalography correlated functional Magnetic Resonance Imaging (EEG-fMRI) is a multi-modal imaging technique with growing application in the clinical evaluation of epilepsy. In this work, a new approach for simultaneously recorded EEG-fMRI data integration of ictal events in epilepsy is proposed. To improve the fMRI artefact correction of EEG data, a fully automated algorithm was developed based on existing tools. Independent component analysis (ICA) decomposition was performed on the corrected EEG data and multiple model based metrics were applied to the resulting time courses. These were used to predict the Blood Oxygen Level Dependent (BOLD) fMRI data using a General Linear Model (GLM) approach. When compared with the conventional fMRI data analysis based on square waveform descriptions of seizure activity, clinically valid and more significant activations were found with the method proposed here, for the four patients studied. In particular, frequency-weighted EEG metrics were found to best describe the BOLD signal, in support of previous theoretical and experimental work. In general, the results were consistent with the neurophysiologist's expectation, but further validation using more direct measurements of seizure activity is necessary. A detailed study on the hemodynamic response function (HRF) to the EEG metrics was performed for one patient. The HRFs estimated were broader than the canonical HRF and the distributions of its delay and dispersion were mapped throughout the patient's brain. In summary, this work contributed to a better understanding and improved integration of EEG-fMRI data collected during epileptic seizures.

Keywords: BOLD, EEG-fMRI, HRF, epilepsia.

Members of the Thesis Committee:
Prof. Fernando Lopes da Silva
Prof. Patrícia Figueiredo
Dr. Alberto Leal
Prof. João Sanches
Prof. Sónia Gonçalves

Ana Rita Gafaniz, "Modeling of the Haemodynamic Response Function based on Physiological Principles, M.Sc.. Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2010.

Abstract: Functional Magnetic Resonance Imaging (fMRI) is a widely used method to study and evaluate brain neural processes. The most common fMRI technique employs the *Blood-Oxygenation- Level-Dependent* (BOLD) contrast, which is based on the correlation between the *haemodynamic response function* (HRF) and the neuronal activity. However, since the BOLD effect is small and data is noisy, analyzing this information is difficult. Therefore, an accurate knowledge of the response of the BOLD signal to a localized neural stimulus is critical, in order to interpret the fMRI data confidently.
Among the overall mechanisms involved in this relation, four main components can be identified:
i) *Adenosine Tri-Phosphate* (ATP) consumption, mainly in order to reestablish intra and extracellular ionic *homeostasis* that are degraded due to the neuronal activity, ii) ATP regeneration, aiming at meet the cell energy demand, iii) oxygen (O2) consumption, for the aerobic energy metabolism, and blood-brain barrier O2 diffusion, iv) blood flow dynamics and venous dilation processes.

In this thesis, it is proposed a physiologically-based model for first two components described above. Thus, the presented *Neuro-Metabolic Model* (NMM) establishes the relation between the energy metabolism and the corresponding neuronal electrical activity, with the ultimate goal of modelling the relationship between blood oxygenation dynamics and the neuronal activity. The NMM is tunned with physiological information obtained from the literature. The critical elements involved in ATP dynamics, within the neuron, are the sodium/potassium pump and the mitochondrion, which are respectively associated with ATP expenditure and regeneration. From a Control theory perspective, the mitochondrial respiration, i.e., the preferable biochemical mechanism that restores ATP, is modeled as a classic regulator, that promotes the ATP *homeostasis*. The proposed model, a second order linear system with double pole and no zeros, is able to describe the complex physiological mechanisms involved in the neuronal activity and is useful to model the overall HRF.

Keywords: fMRI, BOLD, Neuronal Electrical Activity, Energy Metabolism, Neuro-Metabolic Model.

Members of the Thesis Committee:
Prof. Fernando Henrique Lopes da Silva (IST)
Prof. João Miguel Raposo Sanches (IST)
Prof. João Manuel Lage de Miranda Lemos (IST)

Guilherme Carvalho, "Continuous ECG Acquisition Holter System with mobile phone", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal.

Miguel Rodrigues, "ASL Adaptive Optimal Sampling Strategy (AOSS)", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal.

2.3.2 Theses in Progress during 2010

In this subsection the Doctoral and Master theses in progress during 2010, at ISR/IST (ECE) and ISR/Algarve (ECE), are identified and ordered by the scientific research area:

DOCTORAL THESES (68)

Research Area: Cooperative Perception
Title: Active Cooperative Perception in Networked Robot Systems
Doctoral Student: Abdolkarim Pahliani
Advisor: Pedro Lima
Initiated: February 2005
Expected conclusion: 2011
Current Status: Dissertation under final review
Grant: FCT
Documents produced in 2010:
A. Pahliani, M. Spaan, P. Lima, "Fault-tolerant Probabilistic Sensor Fusion for Distributed Multi-Agent Systems", *Proc. of IROS 2010 - IEEE/RSJ International Conference on Intelligent Robots and Systems*, Taipei, Taiwan, October 2010.

Research Area: Robotic tasks modelling and supervision using DES theory
Doctoral Student: Bruno Lacerda
Advisor: Pedro Lima
Initiated: September 2008
Expected conclusion: 2012
Current Status: On-going, thesis work
Grant: FCT

Research Area: Planning under uncertainty for multi-robot systems
Doctoral Student: João Messias
Advisors: Pedro Lima, Matthijs Spaan
Initiated: September 2008
Expected conclusion: 2012
Current Status: On-going, thesis work
Grant: FCT
Documents produced in 2010:
J. Messias, M. Spaan, P. Lima, "Multi-robot planning under uncertainty with communication: a case study", AAMAS 2010 Workshop on Multi-Agent Sequential Decision Making in Uncertain Domains, Toronto, Canada, May 2010.

Research Area: Institutional robotics, swarm robotics
Doctoral Student: José Nuno Pereira
Advisor: Pedro Lima, Alcherio Martinoli (EPFL)
Initiated: September 2008
Expected conclusion: 2012
Current Status: On-going, thesis work
Grant: FCT (IST/EPFL dual degree PhD program)
Documents produced in 2010:
J. N. Pereira, A. L. Christensen, P. Silva, P. Lima, "Coordination Through Institutional Roles in Robot Collectives", Proc. of AAMAS 2010 - 9th International Conference on Autonomous Agents and Multiagent Systems, Toronto, Canada, May 2010.

Research Area: Cooperative Perception
Doctoral Student: Aamir Ahmad
Advisor: Pedro Lima
Initiated: September 2008
Expected conclusion: 2012
Current Status: On-going, PhD thesis and coursework
Grant: FCT PCMMC project
Documents produced in 2010:
P. Lima, J. Santos, P. Santos, R. Oliveira, A. Ahmad, "Cooperative Localization Based on Visually Shared Objects", Proc. of RoboCup2010 Symposium, Singapore, June 2010.

Research Area: Planning under uncertainty for Network Robot Systems
Doctoral Student: Tiago Veiga
Advisor: Matthijs Spaan
Initiated: June 2010
Expected conclusion: 2014
Current Status: On-going, thesis work
Grant: Dec-PUCS project (FCT grant started Jan 2011)

Documents produced in 2010:

M. T. J. Spaan, T. S. Veiga, and P. U. Lima, "Active Cooperative Perception in Network Robot Systems Using POMDPs", Proc. *of IROS 2010 - IEEE/RSJ International Conference on Intelligent Robots and Systems*, Taipei, Taiwan, October 2010.

Research Area: Management of Energy Consumption in Buildings
Doctoral Student: Pedro Fazenda
Advisor: Pedro Lima
Initiated: September 2009
Expected conclusion: 2013
Current Status: On-going, thesis work
Grant: FCT (MIT-Portugal program)

Research Area: Binding perception to action: a cognitive architecture for robots
Doctoral Student: Bruno Nery
Advisor: Rodrigo Ventura
Initiated: September 2009
Expected conclusion: 2013
Current Status: On-going, PhD coursework
Grant: FCT

Research Area: Neurofeedback non-invasive BCI approach for robotic teleoperation
Doctoral Student: David Belo
Advisor: Rodrigo Ventura, João Sanches
Initiated: September 2009
Expected conclusion: 2013
Current Status: On-going, PhD coursework
Grant:

Research Area: Active Surveillance
Title: N/A
Doctoral Student: Nelson Gonçalves
Advisor: João Sequeira
Initiated: 2002
Expected conclusion: 2011
Current Status: On-going, PhD coursework
Grant: FCT
Documents produced in 2010:

-N. Gonçalves, J. Sequeira, "Mixing Differential Inclusions with Markov Decision Processes", Proc. of IROS 2010 - IEEE/RSJ International Conference on Intelligent Robots and Systems, Taipei, October, 2010.

-M. T. J. Spaan, N. Gonçalves, J. Sequeira, "Multirobot Coordination by Auctioning POMDPs", Proc. of ICRA 2010 - IEEE International Conference on Robotics and Automation, Anchorage, Alaska, May 2010.

-N. Gonçalves, J. Sequeira, "Robust Multi-robot Task Assignment in Surveillance", Proc. IAV 2010 - 7th IFAC Symposium on Intelligent Autonomous Vehicles, Lecce, Italy, September 2010.

Research Area: Underwater Acoustics Signal Processing
Title: Parameter Estimation with High-Frequency Signals using a Vector Sensor Array in the Ocean Environment
Doctoral Student: Paulo Santos
Advisor: Paulo Felisberto and Sérgio Jesus (UAlg/ISR)

Initiated: 2007
Expected conclusion: 2011
Current Status: On-going
Grant: FCT
Documents produced in 2010:
-P. Santos, P. Felisberto, S. M. Jesus, J. João, "Experimental Results of Geometric and Geoacoustic Parameter Estimation Using a Vector Sensor Array*", IX ETAS - IX Encontro de Tecnologia Acustica Submarina*, Arraial do Cabo, Brasil, November 2010.
-P. Santos, O. C. Rodríguez, P. Felisberto and S. M. Jesus, "Seabed geoacoustic characterization with a vector sensor array*", Journal of the Acoustical Society of America*, 128, No. 5, pp. 2652-2663, November 2010.
-P. Santos, P. Felisberto and S. M. Jesus, "Vector Sensor Arrays in Underwater Acoustic Applications", Proc. DoCEIS 2010 - Doctoral Conference on Computing, Electrical and Industrial Systems, Lisbon, Portugal, February 2010.
-**P. Felisberto, P. Santos and S. M. Jesus**, "Tracking source azimuth using a single vector sensor", Proc. of SENSORCOMM 2010 – 4th International Conference on Sensor Technologies and Applications, Venice, Italy, July 2010.

Research Area: Underwater Acoustics
Title: N/A
Doctoral Student: Nelson Martins
Advisor: Sérgio Jesus (UAlg/ISR)
Initiated: 2007
Expected conclusion: 2010
Current Status: On-going
Grant: FCT
Documents produced in 2010:
-N. Martins, L. Calado, A. C. de Paula and S. M. Jesus, "Classification of three-dimensional ocean features using three-dimensional empirical orthogonal functions", Proc. of ECUA 2010 - 10th European Conference on Underwater Acoustics, Istanbul, Turkey, July 2010.
- N. Martins and S. M. Jesus, "From oceanographic to acoustic forecasting: acoustic model calibration using in situ acoustic measures", IX ETAS - IX Encontro de Tecnologia Acustica Submarina, Arraial do Cabo, Brasil, November 2010.

Research Area: Computer Vision
Title: 3D Surface Matching
Doctoral Student: Roberto Lam
Advisor: Hans du Buf (UAlg/ISR)
Initiated: 2007
Expected conclusion: 2012
Current Status: On-going
Grant:

Research Area: Computer Vision
Title: Face and object recognition by 3D cortical representations
Doctoral Student: Jaime Carvalho Martins
Advisor: Hans du Buf e João Rodrigues (UAlg/ISR)
Initiated: 2008
Expected conclusion: 2012

Current Status: On-going
Grant: FCT

Research Area: Underwater Acoustics
Title: N/A
Doctoral Student: Fábio Lopes
Advisor: Sérgio Jesus (UAlg/ISR)
Initiated: 2009
Expected conclusion: 2012
Current Status: On-going
Grant: Brazilian Navy

Research Area: Underwater Acoustics
Title: N/A
Doctoral Student: Ana Bela Santos
Advisor: Paulo Felisberto and Sérgio Jesus (UAlg/ISR)
Initiated: 2010
Expected conclusion: 2013
Current Status: On-going
Grant: FCT

Research Area: Medical Imaging - Ultrasound
Title: Characterization the Carotid Arteries and Atherosclerotic Disease with 3D Ultrasound.
Doctoral Student: José Seabra
Advisor: João Sanches
Initiated: 2007
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Biological Imaging
Title: Cell nucleus Reconstruction from fluorescence confocal microscopy images.
Doctoral Student: Isabel Rodrigues
Advisor: João Sanches
Initiated: 2006
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Medical Imaging - Ultrasound
Title: Diagnosis and Characterization of the Liver Pathologies from Ultrasound images
Doctoral Student: Ricardo Ribeiro
Advisor: João Sanches
Initiated: 2007
Expected conclusion: 2011
Current Status: On-going
Grant:

Research Area: Medical Imaging – functionalMRI
Title: Bayesian Detection Algorithms for functional MRI
Doctoral Student: David Afonso
Advisor: João Sanches
Initiated: 2009
Expected conclusion: 2013
Current Status: On-going
Grant:

Research Area: Biomedical Signal Processing
Title: Statistical Signal Processing Algorithms for the Diagnosis of Sleep Disorders
Doctoral Student: Alexandre Domingues
Advisor: João Sanches and Teresa Paiva
Initiated: 2009
Expected conclusion: 2013
Current Status: On-going
Grant: FCT

Research Area: Sensor Networks
Title: Simultaneous localization andtracking in sensor networks
Doctoral Student: Pinar Oguz-Ekim
Advisor: João Pedro Gomes, Paulo Oliveira
Initiated: 2007
Expected conclusion: 2012
Current Status: On-going
Grant: FCT
Documents produced in 2010: 1 conference paper (ICASSP'10, Dallas, USA), 1 submitted journal paper (IEEE Transactions on Signal Processing)

Research Area: Sensor networks
Title: Diffusive source localization and reconstruction of diffusive fields using sensor networks
Doctoral Student: Sabina Zejnilovic
Advisor: João Pedro Gomes
Initiated: 2009
Expected conclusion: 2014
Current Status: On-going
Grant: ISR grant
Documents produced in 2010: 1 technical report

Research Area: Underwater acoustics, wireless communications
Title: High-frequency ocean tomography using communications signals
Doctoral Student: Ehsan Zamanizadeh
Advisor: João Pedro Gomes, José Bioucas Dias
Initiated: 2009
Expected conclusion: 2014
Current Status: On-going
Grant: FCT project grant (PHITOM)
Documents produced in 2010: 2 conference papers (ECUA'10, Istanbul, Turkey; OCEANS'10, Seattle, USA)

Research Area: Sensor networks
Title: Air quality monitoring using vehicle-borne sensors
Doctoral Student: Caitlin Forschner
Advisor: João Pedro Gomes
Initiated: 2010
Expected conclusion: 2015
Current Status: On-going
Grant: FCT grant (IST-CMU)

Research Area: Consensus Algorithms for Sensor Networks
Title: Not defined
Doctoral Student: Dusan Djakovetic
Advisor: João Xavier (ISR/IST) and José Moura (CMU)
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: FCT
Documents produced in 2010:
-D. Jakovetic, J. Xavier and J. M. F. Moura,"Consensus in correlated random topologies: weights for finite time horizon", *Proc. of ICASSP 2010 - IEEE International Conference on Acoustics, Speech and Signal*, Dallas, Texas, USA, March 2010.
-D. Jakovetic, J. Xavier and J. M. F. Moura, "Cooperative convex optimization in networked systems: augmented Lagrangian lgorithms with directed gossip communication", submitted to IEEE Transactions on Signal Processing.

Research Area: Sensor Selection Techniques for Sensor Networks
Title: Not defined
Doctoral Student: Dragana BAJOVIC
Advisor: João Xavier (ISR/IST) and Bruno Sinopoli (CMU)
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: FCT
Documents produced in 2010:
-D. Bajovic, D. Jakovetic, J. Xavier, B. Sinopoli and J. M. F. Moura, "Distributed detection over random networks: a large deviations analysis", Proc. of 48th Allerton Conference on Communication, Control, and Computing, Illinois, USA, October 2010.
-D. Bajovic, B. Sinopoli and J. Xavier, "Sensor selection for event detection in wireless sensor networks", submitted to IEEE Transactions on Signal Processing.
-D. Bajovic, D. Jakovetic, J. Xavier, B. Sinopoli and J. M. F. Moura, "Distributed detection over random networks: large deviations performance", submitted to IEEE Transactions on Signal Processing.

Research Area: Distributed Algorithms for Basis Pursuit
Title: Not defined
Doctoral Student: João Mota
Advisor: João Xavier (ISR/IST), Pedro Aguiar (ISR/IST) and Markus Pueschel (CMU)
Initiated: 2008
Expected conclusion: 2012

Current Status: On-going
Grant: FCT

Research Area: Computer vision
Title: Not defined
Doctoral Student: José Jerónimo Rodrigues
Advisor: João Xavier (ISR/IST), Pedro Aguiar (ISR/IST) and Takeo Kanade (CMU)
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Inference in Large-Scale Networks
Title: Not defined
Doctoral Student: Augusto Santos
Advisor: João Xavier (ISR/IST) and José Moura (CMU)
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Optimization on Riemannian Manifolds
Title: Not defined
Doctoral Student: Pedro Guerreiro
Advisor: João Xavier
Initiated: 2009
Expected conclusion: 2013
Grant: FCT

Research Area: Machine Learning
Title: Not defined
Doctoral Student: André F. T. Martins
Advisors: Mário A. T. Figueiredo, Pedro M. Q. Aguiar
Initiated: 2007
Expected conclusion: 2011
Current Status: On-going
Grant: FCT, PT-CMU
Documents produced in 2010:
-A. F. T. Martins, N. A. Smith, E. P. Xing, P. M. Q. Aguiar, and M. A. T. Figueiredo, "Turbo Parsers: Dependency Parsing by Approximate Variational Inference", Proc. of *EMNLP 2010 - SIGDAT Conference on Empirical Methods in Natural Language Processing*, Cambridge MA, USA, October 2010.
-A. F. T. Martins, N. A. Smith, E. P. Xing, P. M. Q. Aguiar, and M. A. T. Figueiredo, "Online MKL for Structured Prediction", Proc. of NIPS Workshop on New Directions in Multiple Kernel Learning, Vancouver, B.C., Canada, December 2010.
-A. F. T. Martins, N. A. Smith, E. P. Xing, P. M. Q. Aguiar, and M. A. T. Figueiredo, "Augmenting Dual Decomposition for MAP Inference", Proc. of NIPS Workshop on Optimization for Machine Learning, Vancouver, B.C., Canada, December 2010.

Research Area: Computer Vision
Title: Not defined
Doctoral Student: Rui F. C. Guerreiro
Advisor: Pedro M. Q. Aguiar
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: FCT
Documents produced in 2010:
-R. F. C. Guerreiro and P. M. Q. Aguiar, "Learning Simple Texture Discrimination Filters", Proc. of ICIP 2010 - IEEE International Conference on Image Processing, Hong Kong, September 2010.

Research Area: Computer Vision
Title: Matching and reconstruction of rigid scenes
Doctoral Student: Manuel Ricardo Marques
Advisor: Joao Costeira
Initiated: 2007
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Computer Vision
Title: Machine Learning in Computer Vision
Doctoral Student: Ricardo Cabral
Advisor: João Paulo Costeira
Initiated: 2009
Expected conclusion: 2014
Current Status: On-going
Grant: FCT – Cmu-Portugal Program

Research Area: Computer Vision
Title: Recognition from multiple cues.
Doctoral Student: Susana Brandão
Advisor: João Paulo Costeira
Initiated: 2009
Expected conclusion: 2014
Current Status: On-going
Grant: FCT – CMU-Portugal Program

Research Area: Telecom Policy
Title: Illegal Transfer of Copyrighted Material with P2P networks
Doctoral Student: Alexandre Mateus
Advisor: Pedro Ferreira, Jon Peha (CMU)
Initiated: 2008
Expected conclusion: 2011
Current Status: On-going
Grant: CMU-Portugal
Documents produced in 2010: 2 journal papers on Telecom Policy Research

Research Area: Telecom Policy
Title: Secondary Markets for Efficient Spectrum Allocation
Doctoral Student: Ram Saruthi
Advisor: Pedro Ferreira, Luis Correia, Jon Peha (CMU)
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: CMU-Portugal
Documents produced in 2010: 1 conference paper (CrownCom)

Research Area: Telecom Policy
Title: Segmented Regulation for Next Generation Networks
Doctoral Student: Miguel Godinho Matos
Advisor: Pedro Ferreira, Marvin Sirbu (CMU)
Initiated: 2009
Expected conclusion: 2012
Current Status: On-going
Grant: CMU-Portugal
Documents produced in 2010: 1 report and qualifier paper

Research Area: Telecom Policy
Title: The effects of spectrum policy on 3G penetration
Doctoral Student: Moinul Zaber
Advisor: Pedro Ferreira, Marvin Sirbu (CMU)
Initiated: 2009
Expected conclusion: 2013
Current Status: On-going
Grant: CMU-Portugal
Documents produced in 2010: 1 report and qualifier paper

Research Area: Telecom Policy
Title: Future Internet Architectures
Doctoral Student: Patrick Agyapong
Advisor: Pedro Ferreira, Marvin Sirbu (CMU)
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: CMU-Portugal
Documents produced in 2010: 1 report and qualifier paper

Research Area: Telecom Policy
Title: Contagious Churn in Cell Phone Networks
Doctoral Student: Qiwei Han
Advisor: Pedro Ferreira, Rahul Telang (CMU)
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going
Grant: CMU-Portugal

Research Area: Telecom Policy
Title: The effects of broadband in schools
Doctoral Student: Ryan Turner
Advisor: Pedro Ferreira, Rahul Telang (CMU)
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going
Grant: CMU-Portugal

Research Area: Computer and Robot Vision
Title: Language Acquisition in Humanoid robots
Doctoral Student: Karl Jonas Hornstein
Advisor: José Santos-Victor
Initiated: 2008
Expected conclusion: 2012
Current Status:
Grant: Project

Research Area: Computer and Robot Vision
Title: Visual sensor design and evolution
Doctoral Student: Jonas Ruesch
Advisor: Alexandre Bernardino
Initiated: 2008
Expected conclusion: 2012
Current Status:
Grant: FCT

Research Area: Computer and Robot Vision
Title: Model based Visual tracking
Doctoral Student: Matteo Taiana
Advisor: Alexandre Bernardino
Initiated: 2008
Expected conclusion: 2012
Current Status:
Grant: FCT

Research Area: Computer and Robot Vision
Title: Learning how to Grasp
Doctoral Student: Ravin de Souza
Advisor: José Samtos-Victor
Initiated: 2010
Expected conclusion: 2013
Current Status:
Grant: FCT

Research Area: Biomedical Engineering
Title: Análise da Microestrutura do EEG do Sono por ondeletas e Sintonia do detector por Computação Evolutiva
Doctoral Student: Rogério Largo
Advisor: Agostinho Rosa
Initiated: 2005
Expected conclusion: 2011
Current Status: Writing thesis
Grant: EST-IPS

Research Area: Biomedical Engineering
Title: Algoritmo para Evolução de Matrizes de pesos por Alinhamento Múltiplo Inverso de Sequências Proteicas
Doctoral Student: Nelson Pereira
Advisor: Agostinho Rosa
Initiated: 2005
Expected Conclusion: 2011
Current Status: on going
Grant: FCT

Research Area: Biomedical Engineering
Title: Processamento e Classificação de Eventos Fasicos no Sono
Doctoral Student: Daria Migotina
Advisor: Agostinho Rosa
Initiated: 2006
Expected Conclusion: 2011
Current Status: Finishing dissertation
Grant: FCT

Research Area: Bio-inspired Computing
Title: Simulator of Artificial Immune System
Doctoral Student: Nuno Fachada
Advisor: Agostinho Rosa
Initiated: 2008
Expected Conclusion: 2012
Current Status: started
Grant: FCT

Research Area: Bio-inspired Computing
Title: Exams Timetabling by Evolutionary Computing
Doxtoral Student: Nuno Leite
Advisor: Agostinho Rosa
Initiated: 2010
Expected Conclusion: 2015
Current Status: started
Grant: ISEL

Research Area: Biomedical Engineering
Title: Desenvolvimento de métodos quantitativos para imagem funcional por ressonância magnética.
Doctoral Student: Inês Nunes de Sousa
Advisor: Patrícia Figueiredo
Co-Advisor: João Seabra (Siemens Healthcare, Portugal)
Initiated: 2009
Expected conclusion: 2012
Current Status: On-going
Grant: FCT – Empresas

Research Area: Dynamic Systems and Autonomous Robotics
Title: Nonlinear systems for target tracking and Integrated Aided Navigation in Autonomous Robotics

Doctoral Student: Tiago Gaspar
Advisor: Paulo Oliveira
Initiated: 2009
Expected conclusion: 2013
Current Status: On-going
Grant: FCT

Research Area: State estimation: theory and practice
Title: Nonlinear Robust Adaptive State Estimation
Doctoral Student: Mohammadreza Bayat
Advisor: António Pedro Aguiar
Initiated: 2007
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Control and Decision systems
Title: Applications of Mean Field Games to ECE
Doctoral Student: Sergio Daniel Pequito
Advisor: A. Pedro Aguiar (DEEC - IST), Bruno Sinopoli (ECE - CMU), Diogo Gomes (Math - IST)
Initiated: 2009
Expected conclusion: 2013
Current Status: On-going
Grant:FCT (ICTI /CMU-Portugal)

Research Area: Control Systems
Title: Distributed Control of Multiple Autonomous Robotic Vehicles
Doctoral Student: Jorge Miguel Soares
Advisor: António Pedro Aguiar
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going
Grant: FCT

Research Area: Networked Control Systems
Title: Networked Control Systems
DoctoralStudent: Daniel Silvestre
Advisor: Carlos Silvestre
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going
Grant: FCT

Research Area: Networked Control Systems
Title: Networked Control Systems
DoctoralStudent: Daniel Silvestre
Advisor: Carlos Silvestre
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going

Grant: FCT

Research Area: Hybrid Control
Title: Hybrid Control for Time-Varying Systems with Application to Aircraft Flight Transition
Doctoral Student: Pedro Casau
Advisor: Carlos Silvestre
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going
Grant: FCT

Research Area: Distributed estimation and nonlinear systems
Title: Networked Estimation and Decision Systems for Multiple Autonomous Robotic Vehicles.
Doctoral Student: Daniel Viegas
Advisor: Paulo Oliveira and Carlos Silvestre
Initiated: 2010
Expected conclusion: 2014
Current Status: On-going
Grant: FCT

Research Area: Nonlinear systems, Attitude estimation
Title: Nonlinear Attitude Observers with Application to Autonomous Vehicles.
Doctoral Student: Sérgio Brás
Advisor: Carlos Silvestre and Paulo Oliveira
Initiated: 2008
Expected conclusion: 2013
Current Status: On-going
Grant: FCT

Research Area: Sensor Based Control
Title: Vision Based Control of Autonomous Aircrafts.
Doctoral Student: Pedro Serra
Advisor: Carlos Silvestre and Rita Cunha
Initiated: 2008
Expected conclusion: 2013
Current Status: On-going
Grant: FCT

Research Area: Nonlinear Control
Title: Advanced Stabilization and Control Techniques for Systems in SE(3).
Doctoral Student: David Cabecinhas
Advisor: Carlos Silvestre
Initiated: 2007
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Networked Control Systems
Title: Formation Control of Autonomous Vehicles.

Doctoral Student: João Almeida
Advisor: Carlos Silvestre and AntónioPascoal
Initiated: 2007
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Navigation Systems and Robotics
Title: USBL Based Navigation Systems for Underwater Vehicles.
Doctoral Student: Marco Martins Morgado
Advisor: Paulo Oliveira and Carlos Silvestre
Initiated: 2007
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Sensor Based Control
Research Area: Networked Control Systems
Title: Sampled Data Systems Control Theory with Application to Networked Control Systems.
Doctoral Student: Duarte Antunes
Advisor: Carlos Silvestre and João Hespanha
Initiated: 2006
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Sensor Based Control
Title: Terrain and Structure Avoidance Control for Robotic Helicopters.
Doctoral Student: Bruno Guerreiro
Advisor: Carlos Silvestre
Initiated: 2007
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

MASTER THESES (19)

Research Area: Petri net models of Robot Tasks
Title: Cooperative Behaviors for Soccer Robots
Master Student: Gonçalo Paiva
Advisor: Pedro Lima
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Formation Control
Title: Formation Control for Unmanned Aerial Vehicles (quadcopters): vision and control
Master Student: Henrique Silva
Advisor: Pedro Lima

Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Middleware for robots
Title: Formation Control for Unmanned Aerial Vehicles (quadcopters): middleware
Master Student: Américo Ambrósio
Advisor: Pedro Lima
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Middleware for robots
Title: Distributed Middleware and Development System for Multi-Robot Systems
Master Student: João Reis
Advisor: Pedro Lima
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Field Robotics
Title: Mapping using forward sensor models
Master Student: João Carvalho
Advisor: Rodrigo Ventura
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Field Robotics
Title: Vision-SLAM in a field robot
Master Student: Filipe Jesus
Advisor: Rodrigo Ventura
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Unmanned Aerial Vehicles
Title: Mapping and semi-autonomous navigation in quadrotors
Master Student: João Mendes
Advisor: Rodrigo Ventura
Initiated: Mar. 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Collective robotics
Title: Landmark-based navigation in collectives of micro-robots
Master Student: Duarte Dias
Advisor: Rodrigo Ventura
Initiated: September 2010

Expected conclusion: 2011
Current Status: ongoing

Research Area: Unmanned Aerial Vehicles
Title: Localization and navigation of a autonomous blimp
Master Student: Rui Nunes
Advisor: Rodrigo Ventura
Initiated: September 2009
Expected conclusion: 2011
Current Status: ongoing

Research Area: Field Robotics
Title: Field robot teleoperation using redundant communication channels
Master Student: Marco Prata
Advisor: Rodrigo Ventura
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Air Traffic Management
Title: Air Traffic Control automation: approach
Master Student: Eduardo Jorge Cardoso Protasio
Advisor: Rodrigo Ventura
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Air Traffic Management
Title: Air Traffic Control automation: ground
Master Student: João Nuno Vieira Figueiredo
Advisor: Rodrigo Ventura
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Air Traffic Management
Title: Air Traffic Control automation: enroute
Master Student: Francisco Manuel de Melo Sousa Jarnac de Freitas
Advisor: Rodrigo Ventura
Initiated: September 2010
Expected conclusion: 2011
Current Status: ongoing

Research Area: Robot dynamics and Control
Title: Modeling and control of a motorbike
Master Student: Marco di Vittori
Advisor: João Sequeira
Initiated: September 2010
Expected conclusion: 2011

Current Status: ongoing

Research Area: Underwater Acoustics
Title: N/A
Master Student: Salman Ijaz
Advisor: Antonio Silva and Sérgio Jesus (UAlg/ISR)
Initiated: 2010
Expected conclusion: 2011
Current Status: On-going
Documents produced in 2010: 3 conference papers.
-S. I. Siddiqui, A .J. Silva and S. M. Jesus, "Doppler domain decomposition of the underwater acoustic channel arriving paths for the CALCOM'10 experiment", IX ETAS - IX Encontro de Tecnologia Acustica Submarina, Arraial do Cabo, Brasil, November 2010.
-S. Ijaz, A. Silva and S .M. Jesus, "Compensating for source depth change and observing surface waves using underwater communication signals", Proc. of International Conference on Sensor Technologies and Applications, Venice, Italy, July 2010.

Research Area: Underwater acoustics, wireless communications
Title: Cooperation between autonomous underwater vehicles with intermittent communications
Master Student: Filipa Mesquita
Advisor: João Pedro Gomes
Initiated: 2010
Expected conclusion: 2011
Current Status: On-going

Research Area: Underwater acoustics, wireless communications
Title: Localization of submerged black boxes in airplane crashes over the ocean
Master Student: André Rocha
Advisor: João Pedro Gomes
Initiated: 2010
Expected conclusion: 2011
Current Status: On-going

Research Area: Sensor networks, air-quality monitoring
Title: Implementation of a vehicular network for air quality monitoring
Master Student: Fábio Gameiro
Advisor: João Pedro Gomes
Initiated: 2010
Expected conclusion: 2011
Current Status: On-going

Research Area: Sensor networks, environmental monitoring
Title: Detection and localization of volcanic emissions from satellite measurements of aerosol optical depth
Master Student: Sérgio Agostinho
Advisor: João Pedro Gomes
Initiated: 2010
Expected conclusion: 2011
Current Status: On-going

2.4 ADVANCED TRAINING

2.4.1 Courses

Agostinho Rosa

- "Polisonografia", Master Course in Science of Sleep, IMM-FMUL.

António Pedro Aguiar

- Nonlinear Systems, Ph.D. Course, IST, Lisbon, Portugal.
- Linear Systems, Ph.D. Course, IST, Lisbon, Portugal.

João Sanches

- Reconstruction of Medical Imaging, PhD Course, IST, Lisbon Portugal.

João Xavier

- Nonlinear Optimization, Phd Course, IST, Lisboa, Portugal.

José Santos-Victor

- Computer Vision, Ph.D. Course, IST, Lisbon, Portugal.

Matthijs Spaan

- Invited one-day course on Partially Observable Markov Decision Processes, atUniversidad Nacional de Educacion a Distancia (UNED), Madrid, Spain.

Paulo Oliveira

- Dynamic Stochastic Estimation, Filtering, Prediction and Smoothing, Ph.D. Course, IST, Lisbon, Portugal.

Pedro Lima and João Sequeira

- Advanced Robotics, Ph.D. Course, IST, Lisbon, Portugal.

2.4.2 Seminars

- **During 2010 the following Seminars were given outside ISR:**

Alexandre Bernardino

- Object Detection and Tracking on the iCub, Workshop iCub and Friends, IROS 2010, Taiwan.

Gustavo Carneiro

- "The Automatic Design of Feature Spaces for Local Image Descriptors using an Ensemble of Non-linear Feature Extractors". Universidade do Porto – ECE Department. Back to Basics Coloquium.

João Pedro Gomes

- "Location-Aware Sensing in Smart Networks", Ciência 2010: Meeting of science and technology in Portugal, Centro de congressos de Lisboa, July 2010.
- "An Overview of the URBISNET Project", Faculty of engineering, Porto University, Porto, November 2010.

João Sanches

- Joint Ph.D Programme on Fusion Science and Engineering, 2nd Advanced Course on Diagnostics and Data Acquisition, 2010.
- Actigraphy Signal Processing, MASTER DEGREE on SLEEP SCIENCES, Sleep and Technology, 2010.

José Santos-Victor

- Reverse Engineering the Brain with Humanoid Robots, invited talk, International Conference on Image Analysis and Recognition, ICIAR 2010, June, 2010. (http://www.iciar.uwaterloo.ca/iciar10/talks.php)
- Bioinspired Robotics and Vision with Humanoid Robots," Keynote speaker, 7th Intl. Conf. on Informatics in Control, Automation and Robotics (ICINCO), Madeira, June 2010.

Danesh Tarapore

- "Modelling collective systems: from cells, to social insects, to robots". Presented at the Indian Institute of Science, Bangalore, India, October 2010.

Rodrigo Ventura

- "Living with [ISR] robots", in workshop "Next generation of robots and virtual companions" (EU LIREC Project), Portugal Tecnológico, Lisbon, September 2010.
- "Métodos de Localização para Robótica Móvel" (Localization Methods for Mobile Robotics), Instituto Politécnico da Guarda, October 2010.

Ruben M.-Cantin

- Towards Closing the Loop: Active Learning for Robotics, Univ. Seville, May 2010,
- Active Learning for Developmental Robotics, Max-Planck Institute, Tuebingen, July.

Matthijs Spaan

- "Decision-theoretic Planning under Uncertainty for Active Cooperative Perception" Laval University, Québec, Canada, May 2010.
- "Decision-theoretic Planning under Uncertainty for Active Cooperative Perception" Priberam Machine Learning seminar, Lisbon, Portugal, June 2010.
- "Decision-theoretic Planning under Uncertainty for Active Cooperative Perception" INESC-ID, Porto Salvo, Portugal, July 2010.
- "Decision-theoretic Planning under Uncertainty for Active Cooperative Perception" Universidad Carlos III de Madrid, Leganés, Spain, July 2010.

Patrícia Figueiredo

- "What can brain images tell us about the brain?", Doctoral Program in Neuroscience, Faculty of Medicine, University of Lisbon, Portugal, November 2010.

Vislab members organized the following conferences / workshops / summer schools:

- "Towards Closing the Loop: Active Learning for Robotics", Full day workshop at Robotics: Science and Systems 2010. Venue: University of Zaragoza, Spain. http://users.isr.ist.utl.pt/~rmcantin/pmwiki/pmwiki.php/RSS10/RSS10
- "iCub and friends: a workshop for open source robotics", held with IEEE Humanoids 2010, Nashville, Tennesse, December 2010. http://eris.liralab.it/wiki/The_iCub_Humanoids_%2710_workshop

- **ISR Regular seminars**

In a regular basis the following seminars were held:

"The algebraic method: a new approach to nonlinear estimation?"
Prof. Jerome Jouffroy
Associate Professor at the Mads Clausen, University of Southern Denmark
January 2010

"Dual Decomposition for Distributed Control"
Anders Rantzer
Department of Automatic Control, University of Lund, Sweden
January 2010

"Robot Task Plan Representation Based on Petri Nets: Modelling, Analysis and Execution"
Hugo Costelha
ISR/IST
January 2010

"Hybrid Approach to Task Planning, Learning and Control Under Uncertainty Based on Discrete Event Systems Supervision and Reinforcement Learning"
Gonçalo Neto
ISR/IST
January 2010

"Factors modulating the efficiency of division of labor in social insect societies"
Danesh Tarapore
ISR/IST
February 2010

"Introduction to the Université de Sherbrooke in Quebec, Canada and its Faculty of Engineering"
Prof. Denis Gingras
March 2010

"Generalized moment problems and spectrum approximation in the Hellinger distance"
Prof. Augusto Ferrante
March 2010

"SAUC-E: Experiences from the Nessie team"
Francesco Maurelli
Ocean Systems Laboratory, Heriot-Watt University
March 2010

"Portuguese Tiles and European Engraving"
Prof. Ana Paula Correia
March 2010

"On the development of an analysis and design tool for manned submarines"
Diana Ovalle
Dep. de Matemática Aplicada y Estadística, ETSI Industriales, Universidad Politécnica de Cartagena
April 2010

"Altitude control of a Seaweed haervester"
Marco Gallieri
ISR/IST

April 2010

"Modeling and analysis of packet forwarding techniques for probabilistic relay networks"
Ioannis Chatzigeorgiou
May 2010

"A Discriminative Constellation Model for Image Matching and Recognition"
Carlo Tomasi
Duke University
May 2010

"Optimal Control on Non-Compact Lie Groups: A Projection Operator Approach"
Alessandro Saccon
ISR/IST
May 2010

"Feedback control of critical nonlinear systems. Application to nonholonomic and underactuated vehicles"
Claude Samson
INRIA, Sophia Antipolis, France
June 2010

"Close to robots: human responses to collaboration with robots"
Prof. Vanessa Evers
University of Amsterdam
September 2010

"A modeling study of the relation between capacity and precision in visuo-spatial working-memory"
Dr. Rita Almeida
Institut d'Investigacions Biomèdiques August Pi i Sunyer, Barcelona, Spain
September 2010

"Disaster Response Robotics"
Prof. Daniele Nardi
Dipartimento di Informatica e Sistemistica
October 2010

"Nonlinear Estimation using Mean Field Games"
Sérgio Pequito
ISR/IST
November 2010

"Reinforcement Learning as Mixture Learning"
Nikos Vlassis
Luxembourg Centre for Systems Biomedicine & OneTree Technologies Luxembourg
November 2010

2.4.3 Visits Abroad

Paulo Felisberto, Nelson Martins, Orlando Rodriguez, Paulo Santos and Salman Ijaz

- Instituto Estudos do Mar Almirante Paulo Moreira (IEAPM), Arraial do Cabo, RJ (Brazil), November 2010.

Sérgio Jesus, Nelson Martins and Paulo Felisberto

- Instituto Estudos do Mar Almirante Paulo Moreira (IEAPM), Arraial do Cabo, RJ (Brazil), March 2010.

Sérgio Jesus

- Department of Oceanic Engineering, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro (Brazil), August 2010.

Usa Vilaipornsawai and António Silva

- Instituto Estudos do Mar Almirante Paulo Moreira (IEAPM), Arraial do Cabo, RJ (Brazil), July 2010.

Pedro Lima

- Sabbatical leave at U. Carlos II de Madrid, under a 6-month Chair of Excellence awarded by its Board of Governors, Feb-July 2010.

2.4.4 Reading Groups

- VisLab weekly seminar meeting.
- Monthly seminars: Brain Imaging Interest (SIPG).
- Brain Imaging Interest Group (BIIG) monthly meetings (organized by P. Figueiredo).
- Patrícia Figueiredo's group weekly meetings.

2.4.5 Supervision of Students Enrolled in Foreign Universities

Alexandre Bernardino

- Afshin Dehghan, BSc student, Univ. of Tehran, Iran
- Ashish Jain, BE student, Manipal Inst. of Technology, India
- Misel Batmendijn (IAESTE), BSc student, Tech. University of Kosice, Slovakia
- Kristijan Petkov, (IAESTE) Univ. St. Cyril and Methodius, Macedonia.
- Urbain Prieur, UPMC, Paris, France. PhD co-tutela IST-UPMC.

José Santos-Victor

- Sebastien Gay, Double degree with EPFL
- Ravin de Souza, Double Degree with EPFL

Carlos Silvestre

- Co-Supervisor of Narcis Palomeras, Ph.D student from Technical University of Catalonia, Girona, Spain.

2.5 CONGRESS, MEETINGS AND PRESENTATIONS

This section includes invited talks, conferences attended and conferences where papers were presented, during 2010, by ISR-Lisbon researchers.

2.5.1 Invited Talks

Isabel Ribeiro

- "The Remote Handling Systems for ITER," Invited Plenary Talk, SOFT 2010 - 26th Symposium on Fusion Technology, Porto, Portugal, 27 September - 1 October 2010.

João Paulo Costeira

- "Guided Search Consensus: Using geometric constraints towards an efficient point matching algorithm". Special Seminar Lecture – Carnegie Mellon University, December 2010.

João Pedro Gomes

- "An Overview of the URBISNET Project", Faculty of engineering, Porto University, Porto, November 2010.

João Sanches

- "Tissue Characterization by Image Analysis for Diagnostic Purposes", Faculty of engineering, Porto University, Porto, November 2010.

Pedro Lima

- *Research on Networked Robot Systems at ISR/IST*, Universidad Carlos III de Madrid / RoboticsLab (23 Mar 2010), Spain;
- Universidad Politécnica de Madrid / DISAM/ETSII (26 April 2010), Spain;
- Universidad Politécnica de Catalonia / IRI (15 June 2010), Spain;
- Universidad Carlos III de Madrid / Planning and Learning Group (5 July 2010), Spain.

2.5.2 Participations

AAMAS 2010 – 9th International Conference on Autonomous Agents and Multi-Agent Systems, Toronto, Canada, May 2010.

ACC 2010 - American Control Conference, Baltimore, Maryland, USA, 2010.

ACM SAC 2010 – 25th ACM Symposium on Applied Computing, Crans-Montana, Switzerland, March 2010.

BICA 2010 – 1st International Conference on Biologically Inspired Cognitive Architectures, Washington D.C., USA, November 2010.

CVPR 2010 – IEEE Conference on Computer Vision and Pattern Recognition, San Francisco, USA, June 2010.

ECUA 2010 – European Conference on Underwater Acoustics, Istanbul, Turkey, June 2010.

ELMAR-2010 - 52nd International Symposium, Zadar, Croacia, 2010.

EMBC 2010 - Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Buenos Aires, Argentina, September 2010.

HBM 2010 - 16th Annual Meeting of the Organization for Human Brain Mapping, Barcelona, Spain, June 2010.

IAV 2010 – 7th IFAC Symposium on Intelligent Autonomous Vehicles, Lecce, Italy, September 2010.

ICAPS 2010 – 20th International Conference on Automated Planning and Scheduling, Toronto, Canada, May 2010.

ICASSP 2010 – International Conference on Acoustics, Speech, and Signal Processing, Dallas, USA, March 2010.

ICIP 2010 - IEEE International Conference on Image Processing, Hong Kong, September 2010.

ICPR 2010 - IAPR International Conference on Pattern Recognition, Istanbul, Turkey, August 2010.

ICRA 2010 – IEEE International Conference on Robotics and Automation, Anchorage, Alaska, USA, May 2010.

IJCCI 2010 – 2rd International Joint Conference on Computational Intelligence, Valencia, Spain, October 2010.

IROS 2010 – The IEEE/RSJ IEEE International Conference on Intelligent Robots and Systems, Taipei, Taiwan, October 2010.

ISBI 2010 – IEEE International Symposium on Biomedical Imaging. Rotterdam, The Netherlands, April 2010.

ISMRM 2010 - 18th Annual Meeting of the International Society for Magnetic Resonance in Medicine, Stockholm, Sweden, May 2010.

NOLCOS 2010 - 8th IFAC Symposium on Nonlinear Control Systems, Bologna, Italy, 2010.

OCEANS'10 MTS/IEEE, Seattle, USA, September 2010.

RECPAD 2010 – 16th Conference on Pattern Recognition, Vila Real, Portugal, October 2010.

RoboCup 2010, Singapore, June 2010.

49th IEEE Conference on Decision and Control, Atlanta, Georgia, USA, 2010.

2.6 SERVICE ACTIVITIES

This section is dedicated to service activities developed, during 2010, by ISR-Lisbon researchers as members of the national and international scientific community.

2.6.1 Editorial Boards

Agostinho Rosa

- Member of the Editorial Board of the International Journal of Information & Communication Technology in Education.

António Pascoal

- Associate Editor, IEEE Oceanic Engineering.

Pedro Lima

- Journal of Advanced Robotic Systems, published by ARS Publishing, Vienna.
- Portuguese Magazine Robotica.

2.6.2 Advisory Boards

Agostinho Rosa

- Member of AWBL – Advances in Web Based Learning Book Series – (2010-2011).

António Aguiar

- Member of the IFAC Technical Committee on Intelligent Autonomous Vehicles

António Pascoal

- Chair of the IFAC Technical Committee on Marine Systems
- Member of the IFAC Technical Committee on Marine Systems
- Vice-President of EurOcean, the European Portal for Marine Science and Technology

Carlos Silvestre

- Member of the IFAC Technical Committee on Aerospace
- Member of the IEEE Technical Committee on Aerospace Control

João Sanches

- Member of the Bio Imaging and Signal Processing Technical Committee (BISP-TC) of the IEEE Signal Processing Society since November 2010.

José Santos-Victor

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

Pedro Lima

- National Delegate to ESA PB-HME (Program Board on Human Activity, Microgravity and Exploration).
- National Delegate to EC FP7 SPACE Program Board.

2.6.3 Programme and Technical Committees

Agostinho Rosa

- Member of the IFAC Technical Committee – Optimal Control.
- Member of the IASTED Technical Committee – Biomedical Engineering.

António Pascoal

- Member of the Technical Committee of the 9th Portuguese Conference on Automatic Control-CONTROLO2010, Coimbra, September 2010.
- Co-chair of the international Program Committee of the 7th IFAC Symposium on Intelligent Autonomous Vehicles, Lecce, Italy, September 2010.

António Aguiar

- Member of the Technical Committee of the 7th IFAC Symposium on Intelligent Autonomous Vehicles, IAV 2010, Lecce, Italy, September 2010.

Carlos Silvestre

- Member of the Technical Committee of the 9th Portuguese Conference on Automatic Control-CONTROLO2010, Coimbra, September 2010.
- Member of the Technical Committee of the 49th IEEE Conference on Decision and Control (CDC 2010), Atlanta, Georgia, USA, December 2010.
- Member of the Technical Committee of the International Conference on Emerging Technologies and Factory Automation, ETFA'2010, Bilbao, Spain,September 2010.
- Member of the Technical Committee of the 7th IFAC Symposium on Intelligent Autonomous Vehicles, IAV 2010, Lecce, Italy, September 2010.

Gustavo Carneiro

- Member of the Program Committee of CRV 2010 – Canadian Conference on Computer and Robot Vision, Ottawa, Canada, May 2010.
- Member of the Program Committee of VISAPP 2010 – International Conference on Computer Vision Theory and Applications, Angers, France, May 2010.
- Member of the Program Committee of CVPR 2010 - Conference on Computer Vision and Pattern Recognition, San Francisco, USA, June 2010.
- Member of the Program Committee of ICISP 2010 – International Conference on Image and Signal Processing, Quebec, Canada, June 2010.
- Member of the Program Committee of MICAI 2010 – Mexican International Conference on Artificial Intelligence, Pachuca, Mexico, November 2010.

Isabel Ribeiro

- International Program Committee Member, ROBÓTICA 2010 - 10th Conference on Autonomous Robot Systems and Competitions.
- International Program Committee Member, IAV 2010 - 7th IFAC Symposium on Intelligent Autonomous Vehicles.

João Sanches

- Member of the Program Committee of MCPR 2010 - Mexican Conference on Pattern Recognition.
- Member of the Program Committee of ISBI 2010 - IEEE International Symposium on Biomedical Imaging.
- Member of the Program Committee of ICASSP 2010 - IEEE International Conference on Acoustics, Speech, and Signal Processing.
- Member of the Program Committee of SiPS 2010 - Workshop on Signal Processing Systems.
- Member of the Program Committee of CIARP 2010 - Iberoamerican Congress on Pattern Recognition. Member of the Program Committee of EMBC 2010 - Conference of the IEEE Engineering in Medicine and Biology Society.
- Member of the Program Committee of ICIAR 2010 - International Conference on Image Analysis and Recognition.
- Member of the Program Committee of CompIMAGE 2010 - Computational Modeling of Objects Presented in Images: Fundamentals, Methods and Applications.

João Sequeira

- International Program Committee Member, ROBÓTICA 2010 - 10th Conference on Autonomous Robot Systems and Competitions.

- International Program Committee Member, CARPI 2010 – 1st International Conference on Applied Robotics for the Power Industry, Montréal, Canada, October, 2010.

Matthijs Spaan

- Program Committee Member, AAMAS 2010 - International Conference on Autonomous Agents and Multi-Agent Systems.
- Program Committee Member, ICAPS 2010 - International Conference on Automated Planning and Scheduling.
- Program Committee Member, ECAI 2010 - European Conference on Artificial Intelligence.
- Prgram Committee Member, STAIRS 2010 – 5th European Starting AI Researcher Symposium.

Patrícia Figueiredo

- VIII Biomedical Engineering Meeting IST-FMUL, Instituto Superior Técnico, Portugal, 3rd November 2010.

Paulo Oliveira

- Member of the Technical Committee of the 18th European Signal Processing Conference - EUSIPCO 2010, Aalborg, Denmark, 2010.
- Member of the Technical Committee of the 9th Portuguese Conference on Automatic Control-CONTROLO2010, Coimbra, September 2010.
- Member of the Technical Committee of the 10th Conference on Mobile Robots and Competitions "ROBOTICA2010," Leiria, March 2010.

Pedro Aguiar

- Member of the Program Committee of ICIP 2010 – IEEE International Conference on Image Processing, Hong Kong, September 2010.

Pedro Ferreira

- Member of the Program Committee of the 1st International Conference on Economics of ICTs, University of Oporto, April 2010.

Pedro Lima

- RoboCup Symposium 2010.
- International Program Committee Member, Robótica 2010 - 10th Conference on Autonomous Robot Systems and Competitions, ROBÓTICA 2010 - 10th Conference on Autonomous Robot Systems and Competitions.
- Program Committee Member, DARS 2010 - Distributed Autonomous Robot Systems.
- Senior Program Committee on Robotics Track, AAMAS 2010 - International Conference on Autonomous Agents and Multi-Agent Systems.

VisLab members were involved in the Program Committee of the following conferences:

- Robotics Science and Systems (RSS)
- Emerging Technologies and Factory Automation, ETFA
- International Conference on Computer Vision Systems, ICVS
- International Conference on Image Analysis and Recognition, ICIAR
- IEEE Intl. Conference on Robotics and Automation, ICRA
- IEEE Computer Society Conf. Computer Vision and Pattern Recognition, CVPR
- IEEE Intl. Conf. on Intelligent Robots and Systems, IROS
- International Conference on Development and Learning, ICDL

2.6.4 Chairperson

Agostinho Rosa

- Track and Session Chair of Computational Intelligence and Image Analysis at ACM SAC 2010.
- Program Chair of IJCCI 2010 – 2rd International Joint Conference on Computational Intelligence, Valencia, Spain, October 2010.

Carlos Silvestre

- Chairman of the session: Fault Diagnosis II, 49th IEEE Conference on Decision and Control (CDC 2010), Atlanta, Geórgia, USA, December 2010.
- Chairman of the session: Networked Control Systems IV, 49th IEEE Conference on Decision and Control (CDC 2010), Atlanta, Geórgia, USA, December, 2010.
- Chairman of the session: Modeling III, 49th IEEE Conference on Decision and Control (CDC 2010), Atlanta, Geórgia, USA, December 2010.
- Chairman of the session: Navigation and Path Planning, American Control Conference (ACC 2010), Baltimore, Maryland, USA, July 2010.

João Sequeira

- Chair of session, CARPI 2010 – 1st International Conference on Applied Robotics for the Power Industry, Montréal, Canada, October, 2010.

Pedro Aguiar

- Session Chair at ICPR 2010 - IAPR International Conference on Pattern Recognition, Istanbul, Turkey, August 2010.
- Session Chair at ICIP 2010 - IEEE International Conference on Image Processing, Hong Kong, September 2010.

2.6.5 Reviewers

Agostinho Rosa

- Algorithms
- BSPC Biomedical Signal Processing & Control.
- IEEE Transactions on Computational Intelligence and Artificial Intelligence in Games.
- IEEE Transactions of Evolutionary Computation.
- IJHIS – Int Journal of Hybrid Intelligent Systems.
- ACHI 2010 – 3rd International Conference on Advances in Computer-Human Interactions.
- AIS 2010 - International Conference on Autonomous and Intelligent Systems.
- BioMed 2010 – 7th IASTED International Conference on Biomedical Engineering
- ICEC 2010 – International Conference on Evolutionary Computation.
- ICEIS 2010 - 12th International Conference on Enterprise Information Systems.
- ICINCO 2010 - 7th International Conference on Informatics in Control, Automation and Robotics.
- RACS 2010 - Reliable and Autonomous Computational Science Conference.
- SAC 2010 - 25th ACM Symposium On Applied Computing.

António Pascoal, Carlos Silvestre, Paulo Oliveira, and António Aguiar

- International Journal of Robust and Nonlinear Control.

- Automatica
- IEEE Journal of Oceanic Engineering.
- IEEE Transactions on Automatic Control.
- IEEE Transactions on Robotics
- IEEE Transactions on Control Systems Technology.

Carlos Bispo

- IFAC 2011 – 18th World Congress of the International Federation of Automatic Control

Carlos M. Fernandes

- IEEE Transactions on Evolutionary Computation
- Journal of Applied Intelligence
- Swarm Intelligence Journal
- IEEE Congress on Evolutionary Computation (CEC) 2011
- Genetic and Evolutionary Computation Conference (GECCO) 2011

Gustavo Carneiro

- IEEE Transactions on Medical Imaging.
- WSCG - Int. Conf. in Central Europe on Computer Graphics, Visualization and Computer Vision.

Isabel Ribeiro

- Elsevier Journal on Fusion Engineering and Design.
- IAV 2010 - 7th IFAC Symposium on Intelligent Autonomous Vehicles.

João Pedro Gomes

- IEEE Transactions on Signal processing.
- IEEE Signal Processing Letters.
- Journal of the Acoustical Society of America.
- IEEE journal of Oceanic Engineering.
- IET Electronics Letters.
- MTS/IEEE OCEANS10 International Conference.
- PIMRC 2010 - IEEE International Symposium on Personal, Indoor and Mobile Radio Communications.
- GLOBECOM 2010 - IEEE Global Communications Conference.

João Sanches

- IEEE Transactions on Medical Imaging – TMI.
- MBEC, Medical and Biological Engineering and Computing - 2010.

João Sequeira

- IEEE Transactions on Instrumentation and Measurement.
- IEEE Transactions on Intelligent Transportation Systems.
- International Journal of Systems Science.
- ICRA 2010 - IEEE International Conference on Robotics and Automation.
- ROBÓTICA 2010 - 10th Conference on Autonomous Robot Systems and Competitions.
- CONTROLO 2010 - 9th Portuguese Conference on Automatic Control.
- ICARV 2010 - 11th International Conference on Control, Automation, Robotics and Vision.
- RO-MAN 2010 - 19th IEEE International Symposium in Robot and Human Interactive Communication.
- CARPI 2010 - 1st International Conference on Applied Robotics for the Power Industry.

Margarida Silveira

- International Journal of Remote Sensing.
- ICIP IEEE International Conference on Image Processing.
- EMBC International Conference of the IEEE Engineering in Medicine and Biology Society.

Matthijs Spaan

- Journal of Artificial Intelligence Research.
- Autonomous Agents and Multi-Agent Systems (JAAMAS).
- Artificial Intelligence.

Patrícia Figueiredo

- Human Brain Mapping.

Pedro Aguiar

- IEEE Transactions on Image Processing.

Pedro Lima

- IEEE Transactions on Robotics and Automation.
- International Journal of Robotics and Automation (Acta Press/IASTED)
- International Journal of Robotics Research (SAGE)
- Springer Journal of Autonomous Agents and Multi-Agent Systems
- Elsevier Journal of Robotics and Autonomous Systems.
- Special Issue on "Ambient Ecologies" of the journal Pervasive and Mobile Computing(Elsevier)
- IROS 2010 (Associate Editor).
- 9th International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS'10) (Senior PC member).

Rodrigo Ventura

- Connection Science.
- IEEE Transactions on Intelligent Transportation Systems.
- Fusion Engineering and Design.
- International Journal of Machine Consciousness.
- Interaction with Computers.

Sérgio Jesus

- Journal of Acoustical Society of America (JASA)
- IEEE Journal of Oceanic Engineering (JOE)
- ACTA ACUSTICA

Vislab members

- Autonomous Robots
- EURASIP Journal on Advances in Signal Processing
- IEEE Transactions:
    + Autonomous Mental Development
    + Biomed Eng.
    + Circuits and Systems for Video Technology
    + Image Proc.
    + Neural Systems & Rehabilitation Engineering
    + PAMI

+ Robotics
+ System Man and Cybernetics

- Intl. Journal of Humanoid Robotics
- Intl. Journal of Robotics Research
- Journal of Robotics and Autonomous Systems
- Journal of Intelligent and Robotic Systems
- Journal of Real-Time Image Processing

2.6.6 Other Activities

Agostinho Rosa

- Evaluation Life action of Marie Curie program – EU.
- Project Evaluation of Cyprus PENEK program.
- Project Evaluation of RTD4 - Technology Enhanced Learning – EU.

Alexandre Bernardino

- IST Dept of Electrical and Computer Engineering, Member of the Board

Isabel Ribeiro

- Adviser to the Board of FCT (Portuguese Foundation for Science and Technology) for the area of R&D projects, with an almost full time occupation. In 2010, responsible for the development of the framework of project funding through FEDER funds, the electronic submission of project cost statements, and discussion of the new project regulations.
- Member of the jury of "Prémio Luís Vidigal" awarded by the Electrical and Computer Engineering Department of IST to the best M.Sc. thesis in the area of Electrical Engineering and Computer Science.

João Paulo Costeira

- National Co-Director of the Dual PhD program in Electrical and Computer Engineering – Carnegie Mellon |Portugal Program.

João Sanches

- President of the Portuguese Association of Pattern Recognition (IAPR) since 2010.

José Santos-Victor

- IST Board Member, Vice-President for International Affairs.
- General Secretary of the CLUSTER network (www.cluster.org).
- IST Director for the IST-EPFL Joint Doctoral Program.

Matthijs Spaan

- AAMAS'10 Tutorial on "Decision Making in Multiagent Systems".
- Organizing committee: AAMAS'10 workshop on "Multi-agent Sequential Decision Making in Uncertain Domains".
- Organizing committee (chair): "POMDP Practitioners Workshop: solving real-world POMDP problems".

Pedro Ferreira

- National Director of the Dual PhD program in Engineering and Public Policy – Carnegie Mellon |Portugal Program.

Pedro Lima

- Member of the Board of Trustees of the RoboCup Federation.
- President of the Portuguese Society of Robotics.
- Blogger in PSR's Robotizando (EXPRESSO newspaper).

Rodrigo Ventura

- Founding member of the Biologically Inspired Cognitive Architectures Society.

Sérgio Jesus

- Project reviewer for the French Agency for Research (ANR).
- Project reviewer for the Greek Ministery of Research and Innovation.

2.7 ACADEMIC ACTIVITIES

Here we list the participation, during 2010, of ISR-Lisbon researchers in committees for Doctoral and Master Theses, and other academic related activities.

Agostinho Rosa

- Member of the Ph.D. Thesis Committee of Claudio Lima – University of Algarve.
- CAT of Hugo Bastos – Science Faculty of Lisbon University.
- Member of the M.Sc. Thesis Committee of Ricardo Costa Figueiredo - IST.
- Member of the M.Sc. Thesis Committee of Joao Cardoso – IST.

Isabel Ribeiro

- Member of the Ph.D. Thesis Committee of José Maria Vasconcelos, "Nonlinear Navigation System Design with Application to Autonomous Vehicles", Instituto Superior Técnico, Lisbon, Portugal, January 2010.

João Paulo Costeira

- Member of the Ph.D. Thesis Committee of Nuno Pinho da Silva, "Robust Nonmetric Perception of Moving Rigid Bodies", Instituto Superior Técnico, Lisbon, Portugal, June 2010.
- Member of the Ph.D. Thesis Committee of Ricardo Jorge dos Santos Ferreira, "Reconstruction of Isometrically Embedded Flat Surfaces From Scaled Orthographic Image Data", Instituto Superior Técnico, Lisbon, Portugal, June 2010.

João Sanches

- Member of the M.Sc. Thesis Committee of Guilherme Luís Teixeira dos Santos, "Chromosome identification and pairing in optical microscopy images", Instituto Superior Técnico, Lisbon, Portugal, December 2010.

João Sequeira

- Member of the Ph.D. Thesis Committee Hugo Costelha, "Robotic Tasks Modeling and Analysis Based on Discrete Event Systems", Instituto Superior Técnico, Lisbon, Portugal, October 2010.
- Member of the Ph.D. Thesis Proposal Committee of Vítor Emanuel Matos, Universidade do Minho.

João Xavier

- Member of the Ph.D. Thesis Committee of Ricardo Jorge dos Santos Ferreira, "Reconstruction of Isometrically Embedded Flat Surfaces From Scaled Orthographic Image Data", Instituto Superior Técnico, Lisbon, Portugal, June 2010.

Jorge S. Marques

- Member of the Ph.D. Thesis Committee of Ricardo Jorge dos Santos Ferreira, "Reconstruction of Isometrically Embedded Flat Surfaces From Scaled Orthographic Image Data", Instituto Superior Técnico, Lisbon, Portugal, June 2010.

Pedro Lima

- Member of the Ph.D. Thesis Committee of Javi Gorostiza, Universidad Carlos II, Madrid, Spain.
- External reviewer of Alejandro Mosteo's Ph.D. Thesis, Universidad de Zaragoza, Spain.

Victor Barroso

- Member of the Ph.D. Thesis Committee of Nuno Pinho da Silva, “Robust Nonmetric Perception of Moving Rigid Bodies”, Instituto Superior Técnico, Lisbon, Portugal, June 2010.
- Member of the Ph.D. Thesis Committee of Ricardo Jorge dos Santos Ferreira, “Reconstruction of Isometrically Embedded Flat Surfaces From Scaled Orthographic Image Data”, Instituto Superior Técnico, Lisbon, Portugal, June 2010.

2.8 VISITS TO ISR

2.8.1 Distinguished Visitors

- **Jim Dai**, Georgia Institute of Technology USA, March 2010.
- **Daniele Nardi**, U. Rome "Sapienza", October 2010
- **Nikos Vlassis**, TU Crete, November 2010.
- **David Lowe** – University of British Columbia, Canada.
- **João Hespanha**, University of California, Santa Barbara. USA.
- **Anders Rantzer**, University of Lund, Sweden.
- **Tarek Hamel**, CNRS, Sophia Antipolis and University of Nice.
- **Claude Samson**, Directeur de Recherche do INRIA Sophia Antipolis, France.
- **Robert Mahony**, Australia National University (ANU). Canberra, Australia. AIAA Journal of Guidance, Dynamics, and Control.
- **Veljko Potkonjac,** Faculty of Electrical Engineering, University of Belgrade, July 2010.

2.9 SPECIAL EVENTS

2.9.1 "Where Computer Vision Meets Arts" – Workshop of the project PRINTART

Museu Nacional do Azulejo, Lisboa, Portugal
June 28, 2010

Coordinator: João Paulo Costeira and Gustavo Carneiro.

Laboratories: Signal and Image Processing Group

Support: *FCT Project PRINTART*.

Description: Workshop that gathered researchers from the areas of computer vision and art history.

URL: http://printart.isr.ist.utl.pt/workshops.htm

2.9.2 OFICINA DE ROBÓTICA - Programme Ciência Viva: Scientific Occupation of Youth during Holidays 2010

Instituto Superior Técnico, Lisbon, Portugal
July 21-25, 2010

Coordinator: Rodrigo Ventura.
Team: Prof. Paulo Oliveira, Prof. João Pedro Gomes.

Laboratories: Intelligent Systems Laboratory.

Support: *Ciência Viva* – National Agency for Scientific and Technological Culture.

Description: 30 high-school students gathered, during 1 week, to build 10 robots from the electronics components up to the controlling software, in order to participate in a simple competition inspired in the RoboCup Rescue Jr. league.

URL: http://mediawiki.isr.ist.utl.pt/wiki/Ocupação_Cient%C3%ADfica_de_Jovens_nas_Férias_2010

2.10 AWARDS AND PATENTS/PROTOTYPES

Patents/Prototypes

- "System and Method for Fetal Biometric Measurements from Ultrasound Data and Fusion of same for Estimation of Fetal Gestational Age", **Gustavo Carneiro**, Sara Good, Bogdan Georgescu, Paolo Favaro, and Dorin Comaniciu, US Patent number 7783095 granted on August 24, 2010.

2.11 PUBLICATIONS

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[3] **João Caxias**, "Contactless Power Supply System for Transmission Line Inspection Robots", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, June 2010.

[4] **Bruno Gomes**, "Control of Autonomous Aircrafts," MSc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, July, 2010.

[5] **Tiago Mestre**, "Communication Interface Between Divers and Ocean Vehicles," M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, July, 2010.

[6] **Nuno Rodrigues**, "Individual andCooperativeBehaviorsRepresentationBasedon Petri Nets", MSc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, October 2010.

[7] **Carlos Martins**, "Goalkeeper Robot Behavior Design and Coordination in Soccer Robotics", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, October 2010.

[8] **Ana Luísa Luís Coito,** "Assessment of the cognitive deterioration in Sleep Apnea Syndrome by spectral analysis of physiological parameters", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

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[10] **Andreia Catarina Costa Duarte,** "Mobile Acquisition Platform for Sleep Assessment", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

[11] **Carlos Alberto Falé Cabral,** "Classificação automática de estados cognitivos em fMRI", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

[12] **Carlos Alves**, "Autonomous Robot Sailboat," MSc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November, 2010.

[13] **Daniel Viegas,** "Navigation Systems for Formations aided by Local Sensors," M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November, 2010.

[14] **João Pedro Forjaco Jorge,** "Sources of signal fluctuations in fMRI at 7 Tesla", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2010.

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[19] **Ana Rita Gafaniz,** "Energy Metabolism and Neuronal Activity: a Physiologically-Based Linear Model for Brain Imaging", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2010.

[20] **João Filipe Teles Ferreira,** "Mobile robot fault-tolerant navigation in nuclear fusion scenarios of ITER", M.Sc. Thesis, Instituto Superior Técnico, DEEC, Lisbon, Portugal, December 2010.

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b) Ph.D. Theses (8)

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[53] **P. Santos, O. C. Rodríguez, P. Felisberto and S.M. Jesus**, "Seabed geoacoustic characterization with a vector sensor array", *Journal of the Acoustical Society of America*, 128, No.5, pp.2652-2663, November 2010.

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e) In International Conferences (148)

[1] **P. Santos, P. Felisberto and S. M. Jesus**, "Vector Sensor Arrays in Underwater Acoustic Applications", *Proc. of DoCEIS 2010 - Doctoral Conference on Computing, Electrical and Industrial Systems*, Lisbon, Portugal, February 2010.

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3 LABORATORY FACILITIES AND SERVICES

3.1 COMMON FACILITIES

The ISR/IST computer network infra-structure is based on 4 PC servers, providing basic services such as mail and web servers, shell accounts, firewall, among others (databases, mailing lists, SVN, FTP, backup, etc.). These servers are located at a data center room with a dedicated AVAC unit. This data center includes equipment from other groups, thus sharing the environmental characteristics of the room. Daily backups are performed of all core servers to a disk array. The firewall provides IP connectivity (both IPv4 and IPv6) to the IST campus network. About 240 users have accounts on the isr.ist.utl.pt domain mail and/or shell, and more than 300 machines, including PCs, SUN workstations, Macintoshes and others, are currently linked to the network, using switching technology (Ethernet 100/1000). Both the core switching technology and the internet access to the campus network uses Gigabit Ethernet technology. Moreover, all ISR facilities are covered by the campus WiFi 802.11b/g network, thus providing wireless access to the Internet to all ISR users.

3.2 LABORATORY FACILITIES

INTELLIGENT ROBOTS AND SYSTEMS GROUP (ISR)

The ISR Group Lab offers the main following facilities:

Robots:

- 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 all-terrain remotely-operated (by wireless or cable LAN) robot (RAPOSA-NG), being a improved version of RAPOSA. It is currently in the process of being equipped with several sensors, including a stereo camera pair on a pan&tilt mount, a Kinect, and a IMU;
- 5 omni-directional (3 wheels) robots endowed with an on-board laptop with wireless communications, rate-gyro, 16 sonars, omni-directional catadioptric system, andelectro-magnetic kicker for robot soccer applications;
- 1 iRobot 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 Robot and Computer Vision Lab);
- 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, with updated electronics (by IdMind) equipped with 16 sonars and 2 cameras each, one of them part of an omni-directional catadioptric system;
- 1 humanoid robot (RobotisBioloid kit).

Computers:

- Several Pentium IV and Centrino Personal Computers (including laptops, 5 of them for the omni-directional robots) – under Linux and Windows OS;
- 3 quad-core workstations, used for running simulations and other experiments requiring fast computation.

Sensors and Communications:

- 3 laser range finder (Hokuyo);
- wireless localization nanoLOC Development Kit 3.0, which provides built-in ranging in the globally available 2.4 GHz ISM band;
- 3 Novatel RTK GPS systems with external antennas;
- 2 Raytheon infrared cameras (one of them installed in the RAPOSA robot);
- 3 wireless Access points (one of which is a high-performance a/b/g/n Cisco wih MIMO techology for diversity);
- 6 Philips 740K USB Web Cams, used in the Super-Scout II robots;
- 1 Real-Time RF video link;
- 1 Kinect;
- 1 MicroStrain IMU;
- 2 Intersense IMU.

Software:

- Matlab and Simulink software for different simulation projects;
- 1 PRO and 1 Student Webots simulator licenses (shared with the Mobile Robotics and Computer and Robot Vision Labs).

The **ISobotNet** is a testbed for Networked Robot Systems developed by the IRS group together with the Computer Vision Lab, composed of an indoor area of around 160 m2 with 10 webcams placed at the ceiling such that some of the fields of view do not overlap. The cameras are distributed in 4 groups, each of which is managed by its own computer, namely for image acquisition. The managing computers are connected to the ISR/IST network and can be accessed by duly authorized external parties. Recently, the number of cameras and the usable indoor space was extended to include multiple floors. Robots will use the same elevators as ordinary people to move between floors. Besides the camera sensors, four Pioneer AT and one ATRV-Jr robots are available. Each of the robots is equipped with sonars, onboard cameras, laser range finder and is Wi-Fi connected to the network. We are currently working on equipping the robots with Microsoft Kinect sensors.

COMPUTER VISION Lab (VISLAB)

- iCub humanoid platform: this humanoid platform was developed within the RobotCub project and, with 54degrees of freedom, it is the most sophisticated humanoid platform worldwide.
- Baltazar Humanoid Torso: composed of a high-speed 4 degrees of freedom binocular head, an articulated arm and hand, for research in learning by imitation. This robot was developed at VisLab since 2001 and was one of the most versatile humanoid robots in Portugal.
- Vizzy –humanoid platform mounted on a Segway mobile base. The first stage of integration was completed in 2010 and software development and integration will be done in 2011. This platform was developed within the lab and combines the flexibility and robustness of Baltazar with mobility. Some parts of the mechanical design were inspired after our design for the iCub.
- One robotic head designed for the iCub, each with 6 degrees of freedom, an inertial sensor, audio and ability to perform facial expressions.
- TRC LabMate mobile platform, equipped different sorts of cameras, including panoramic ones if curved mirrors.
- One Pioneer mobile platform equipped with a Katana manipulator used for experiments in navigation, SLAM or mobile manipulation.
- Two Nomad Superscout mobile platforms, equipped with vision and an on-board computer.
- One Tobii system for gaze tracking.
- One data glove and magnetic tracker.

- The ISobotNet is a tested for Networked Robot Systems developed by VisLab together with the IRSLab, composed of an indoor area of around 160 m2 with 10 webcams placed at the ceiling such that some of the fields of view do not overlap. Besides the camera sensors, four Pioneer AT and one ATRV-Jr robots are available. Each of the robots is equipped with sonars, onboard cameras, laser range finder and is Wi-Fi connected to the network.

SIGNAL AND IMAGE PROCESSING GROUP (SIPG) – LISBON

The SIPG at IST offers the main following facilities:

- 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.

SIGNAL AND IMAGE PROCESSING GROUP (SIPG) – ALGARVE

The SIPG at UALG offers the main following facilities:

- room with research desks divided in cubicles + computer servers (mostly Linux) + printer set (B&W and color), backup and storage systems;
- software resources: Matlab, C and Fortran compilers;
- book literature (computational methods, C and Fortran programming, signal processing, etc.);
- Acoustic Oceanographic Buoy – version 2 (AOB2);
- Acoustic Oceanographic Buoy – version 1 (AOB1);
- Broadband Lubell acoustic source;
- Low frequency acoustic source;
- Ultra Light Vertical Array (ULVA);

The VisLab at UAlg offers the main following facilities:

- 1 room with:
  a) 10 research desks with computers
  b) 1 server
  c) internal 100/1000 Mb computer network w/router, File server, printers
  d) 1 digital microscope with camera Olympus
  e) 1 robot base Surveyor Quad motor base SRV-1 2009
  f) 2 robot head Surveyor Pan/tilt head for SRV-1/SVS
  g) 2 robot vision Surveyor SVS - Stereo vision systems
  h) 2 GPU NVIDIA Tesla C1060

- 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.

DYNAMICAL SYSTEMS AND OCEAN ROBOTICS Lab (DSOR)

DELFIM and DELFIM_X Autonomous Surface Vehicles (ASCs) – designed and built by ISR/IST to carry out experimental research in the area of ocean robotics and to perform scientific missions at sea. DELFIM Length: 3.5m, Width: 2m, Weight: 320 Kg. DELFIMx Length: 4.5 m, Width: 2.4 m, Weight: 300 Kg. Propulsion by electric motors. These vehicles have been used to acquire marine data in the Azores, in cooperation with the partner IMAR/DOP and to carry out experiments on single and multiple vehicle cooperative control.

INFANTE Autonomous Underwater Vehicle (AUV) – designed and built by ISR/IST and the company RINAVE to carry out experimental research in the area of ocean robotics and to perform scientific missions at sea. The vehicle is 4:5m long, 1:1m wide and 0:6m high. It is equipped with two main thrusters (propellers and nozzles) for cruising and fully moving surfaces (rudders, bow planes and stern planes) for vehicle steering and diving in the horizontal and vertical planes, respectively.

MAYA AUV – designed and built by a Luso-Indian consortium consisting of NIO (Goa, India), ISR/IST, IMAR/DOP/UAzores, and RINAVE. A small, modular, autonomous underwater vehicle (AUV) for scientific and commercial applications. Missions include geological and oceanographic surveys, marine habitat mapping, inspection of harbours and estuaries. The first prototype has been tested and used extensively in Goa, India.

CARAVELA 2000 Autonomous Research Vessel – designed and built by IMAR/DOP/UAzores, ISR/IST, and the companies RINAVE. and CONAFI 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).

Autonomous Helicopter (Bergen Industrial Twin) - a small-scale industrial helicopter. This is a transformed radio-controlled helicopter, about 1.6m long (including the rotor diameter), with a payload capability of 10 kg, and a top speed of 70 Km per hour.

IRIS TOOL – designed and built by ISR/IST. A high accuracy surveying tool for both the above water and submerged parts of semi-submerged structures. IRIS is equipped with an accurate Laser Scanner, a profiler sonar, a high end motion reference unit, and a surveying class GPS.

Medusa I – designed and built by ISR/IST. First prototype of a class of semi-submerged vehicles of small size for underwater target positioning. A set of vehicles acting cooperatively will be used in the scope of the EU COGAUVs (Cognitive marine robotics) project for assisted diving operations.

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:

- 3 Quad Core with GTX 9200 GPU
- 2 Netgear (2T + 4T)
- 4 Computadores Core7 with GTS 280
- Impressora HP Laserjet CM 1312

- Scanner HP
- Projector LG
- 2 Server (Linux ,Window);
- 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 Laseeb Sleep Laboratory – Protocol with Meditron

- 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;
- 2 Sonolab 713.