INSTITUTE FOR SYSTEMS AND ROBOTICS

Annual Report – 2009

Lisbon Pole

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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 2009, research activities at ISR/IST were developed essentially in the framework of 33 research projects, 18 under national funding, and 15 under international funding awarded by the EU. The Foundation for Science and Technology (FCT) is the principal source of national funding with 16 research projects. After the description of these projects, the activities reports of the 11 Post-Docs working at ISR/IST are presented.

Four (4) PhD theses and thirty two (32) MSc theses were successfully concluded during 2009. More sixty two (62) PhD and twenty eight 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 researchers coming from international institutions.

Our researchers were invited to give talks in other universities and research institutions, fifteen (15) of them abroad. They participated in a great number of international congresses and meetings. They served as associate or guest editors in seven (7) archive scientific journals, and as members of the advisory boards of eight (8) international organizations. We contributed with more than sixty (60) members of technical and programme committees of a diversity of international conferences and with regular reviewing activities in more than twenty (20) international journals.

We received the visit of approximately twenty (20) distinguished visitors coming from international universities and research institutions in the whole world.

The ISR/IST organized several special events during 2009, namely the series of seminars entitled *From Human Societies to Artificial Societies*, the *ROBOTCUB Meeting*, and a *Robot Learning Summer School*.

The results of the research conducted at ISR/IST was published as five (5) contributions to book chapters, thirty (30) papers in international archive journals, one hundred and twenty (120) communications in proceedings of international conferences. There are also two articles published in national journals and seventeen (17) communications in national conferences.

1 RESEARCH TEAM AND INTERESTS

1.1 MEMBERS AND COLLABORATORS

THEORY GROUP

Michael ATHANS, *Principal Researcher*

INTELLIGENT SYSTEMS

Pedro LIMA, *Associate Professor (IST)*
Carlos BISPO, *Assistant Professor (IST)*
Rodrigo VENTURA, *Assistant Professor (IST)*
Matthijs SPAAN, *Doctoral Researcher (IST)*

Porfírio SILVA, *Post-Doctoral St., FCT grantee*
Alberto REYES, *Post-Doctoral St., FCT project grantee*
Rajneesh SHARMA, *Post-Doctoral St., FCT project grantee*

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João MESSIAS, *Ph.D. St., FCT grantee*
Gonçalo NETO, *Ph.D. St.*
Aamir AHMAD, *Ph.D. St., M.Sc. Research Grantee*
José N. PEREIRA, *Ph.D. St., FCT Grantee (IST/EPFL program)*
Pedro FAZENDA, *Ph.D. St., FCT Grantee (MIT/Portugal program)*
Bruno Nery, *Ph.D. St., FCT Grantee*
David Belo, *Ph.D. St.*

Marco BARBOSA, *EC FP6 URUS Project grantee*
Sónia CABRITA, *ISR grantee*

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Nuno RODRIGUES, *M.Sc. St.*
João SANTOS, *M.Sc. St.*
João ESTILITA, *M.Sc. St.*
Carlos MARTINS, *M.Sc. St.*
Tiago VEIGA, *M.Sc. St.*
Ana Rita MENDES, *M.Sc. St.*
Carlos NEVES, *M.Sc. St.*
Rui NUNES, *M.Sc. St.*
João Filipe Teles FERREIRA, *M.Sc. St.*
Nuno MARQUES, *M.Sc. St.*
Rodrigo BRITO, *M.Sc. St.*
Guilherme SILVA, *M.Sc. St.*
Shadab KHAN, *M.Sc. St., IAESTE grantee*
Manuel JANSEN, *M.Sc. St., IAESTE grantee*

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Ricardo GRIZONIC, *FCT BII*
Ricardo OLIVEIRA, *FCT BII*
João CARREIRA, *FCT BII*
Henrique SILVA, *FCT BII*
João VIANA, *FCT BII*
Guilherme LOPES, *FCT BII*
Pedro VENÂNCIO, *FCT BII*
João REIS, *FCT BII*
João SOUSA, *FCT BII*
Nuno SANTOS, *FCT BII*

COMPUTER AND ROBOT VISION

José SANTOS-VICTOR, *Associate Professor (IST)*
José António GASPAR, *Assistant Professor (IST)*
Alexandre BERNARDINO, *Assistant Professor (IST)*
Luis MONTESANO, *Doctoral Researcher (until Feb. 2009)*
Manuel LOPES, *Doctoral Researcher (until Sep. 2009)*
Giampiero SALVI, *Post-Doctoral St., FCT grantee (until Jun. 2009)*
Ruben MARTINEZ, *Post-Doctoral St., FCT grantee*
Plínio MORENO, *Post-Doctoral St., EU Proj. grantee*

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Ricardo BEIRA, Researcher, *Ph.D. St.*
Bruno DAMAS, *Ph.D. St.*
Jonas HORNSTEIN, *Ph.D. Student*
Pedro Canotilho RIBEIRO, *Ph.D St.*
Jonas RUESCH, *Ph.D. St.*
Dario FIGUEIRA, *Ph.D. Student*

Giovanni SAPONNARO, *M.Sc. St.*
Christian WRESSNEGGER, M.Sc. St.
Lester Garcia, *M.Sc. St.*

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Ricardo NUNES, *Technician*

Daniela PAMPLONA, *external collaborator*
Luis VARGAS, *external collaborator*
Nuno GRACIAS, *external collaborator*

MOBILE ROBOTICS

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João Silva SEQUEIRA, *Assistant Professor (IST)*

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Ernesto SOARES, *Ph.D. St., researcher at IMPBN* Eberhard-Karls University
Fernando MELICIO, *Coordinator Professor ISEL, IPL*

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Dulce CALÇADA, *M.Sc. St.*
João RODRIGUES, *M.Sc. St.*
André ROSADO, *M.Sc. St.*
Luis SANTOS, *M.Sc. St.*
Bruno MARTINS, *M.Sc. St.*
Vitorino RAMOS, *M.Sc. St.*
Alexandre CALAPEZ, *Lic. St.*
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João SEMEDO, *Lic. St., FCT grantee*
Filipe FUNENGA, *Lic St., FCT grantee*

SIGNAL AND IMAGE PROCESSING

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Hans du BUF, *Associate Professor (UALG)*
João XAVIER, *Assistant Professor (IST)*
João Pedro GOMES, *Assistant Professor (IST)*
João SANCHES, *Assistant Professor (IST)*
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Gustavo CARNEIRO, *Visiting Assistant Professor (IST)*
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Paulo FELISBERTO, *Adjoint Professor (UALG)*
Marko BEKO, *Assistant Professor (ULHT)*
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Dragana BAJOVIC, *Ph.D. St., FCT grantee (IST-CMU)*
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Ricardo CABRAL, *Ph.D. St., FCT grantee*
Susana BRANDÃO, *Ph.D. St., FCT grantee*
José SEABRA, *Ph.D. St., FCT grantee*
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Ricardo RIBEIRO, *Ph.D. St., ESTeSL*
David AFONSO, *Ph.D. St.*
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Nelson E. MARTINS, *Ph.D. St., FCT Grantee (UALG)*
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Nuno BARROS, *M.Sc. St.*
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Ricardo Maximiano ALMEIDA, *M.Sc. St.*
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Hugo PINTO, *M.Sc. St.*
Indira ANDRADE, *M.Sc. St.*
João RAMINHOS, *M.Sc. St.*
André BAPTISTA, *M.Sc. St.*
Ricardo SOUSA, *M.Sc. St.*
João JOSÉ, *M.Sc. St.*
Miguel FARRAJOTA, *M.Sc. St.*
Mário SALEIRO, *M.Sc. St.*
Nuno ROSA, *M.Sc. St.*

Salman IJAZ, *Undergrad. St. (UALG)*
Samana MOEINI, *Undergrad. St. (UALG)*

DYNAMICAL SYSTEMS AND OCEAN ROBOTICS

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António PASCOAL, *Associate Professor (IST)*
Carlos SILVESTRE, *Assistant Professor (IST)*

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Rita CUNHA, *Post-Doctoral St.*
Alessandro SACCON, *Post-Doctoral St.*

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André OLIVEIRA, *Research Engineer*
Manuel RUFINO, *Research Engineer*
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Vahid HASSANI, *Ph.D. St., FCT grantee*
Anrdeas HAUSLER, *Ph.D St., Marie Curie Early Stage Researcher*
Pramod MAURYA, *Ph.D. St., FCT grantee*
Marco MORGADO, *Ph.D. St., FCT grantee*
Sérgio PEQUITO, *Ph.D. St., FCT grantee*
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Loic BAMDÉ, *Secretary*

1.2 CURRENT RESEACH INTERESTS

The Lisbon pole of ISR is internally organized in 6 laboratories/groups. In this section the main research interests of each one of the laboratories/groups are briefly described.

1.2.1 Intelligent Systems

The driving theme of the Intelligent Systems Laboratory is the R&D on decentralized decision-making and control for multi-robot (networked, cooperative) systems (main focus), cognitive robots, human-robot interaction, and management systems. Decentralization is a key issue, as the overwhelming amount of information that must be handled in modern systems, composed of a massive number of embedded sensors, actuators, processors, and wireless communication devices, together with the well-known weaknesses of centralized systems, call for novel approaches to decentralized decision-making at different levels of abstraction, using the "think local, act global" principle. Our research is often driven by practical applications, and the applications include monitoring and decision-making in hazardous/remote environments (e.g., space, post-disaster scenarios), and services (e.g., ambient assisted living, helping people in public spaces, energy consumption in buildings).

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, or biological systems, and specific interest on modeling, analysis and synthesis methods.

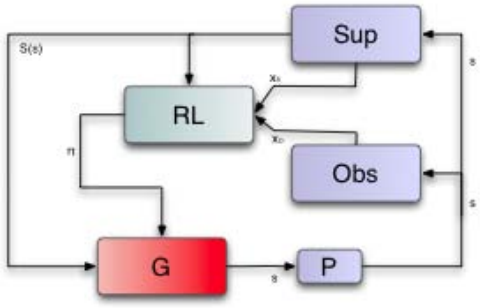
In the following, we provide some details on the research and development topics covered by the Lab members in 2009, as well as on the major results achieved.

Discrete Event System Models of Robotic Plans

Thesis: 3 PhD (Hugo Costelha, Gonçalo Neto, Bruno Lacerda), 2 MSc (Carlos Martins, Nuno Rodrigues)
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 are developing 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



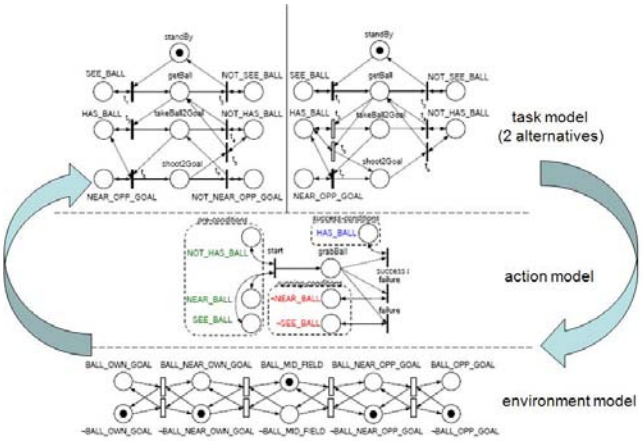
a subset, based on design specifications. RL is used to determine the optimal robot behavior (plan), within the subset of behaviors allowed by the supervisor, iteratively, online and along the robot course of action. Our approach reduces the size of the RL problem and speeds up the convergence to the 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?

(Decentralized) Planning Under Uncertainty

Thesis: 1 PhD (João Messias), 3 MSc (Hugo Augusto, Ana Rita Mendes, Tiago Veiga)
Projects: 1 EU Project (URUS), 1 FCT project (Dec-PUCS)

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.

Lossless clustering of Histories in Decentralized POMDPs: we paper introduced a method for lossless clustering of action-observation histories in Dec-POMDPs, which can be applied in GMAA$*$ policy search for Dec-POMDPs via Bayesian games. Rather than applying an ad-hoc clustering of these BGs, we identified a probabilistic equivalence criterion that guarantees that, given a particular past joint policy, two action-observation histories of an agent at a particular stage have the same optimal Q-values and therefore can be clustered without loss in solution quality. Empirical evaluation of GMAA$*$ demonstrated that for several domains speedups of multiple orders of magnitude are achieved by clustering. We also investigated the amount of clustering possible for random past policies, the result of which suggests that our clustering methods may also be exploited in other algorithms. As such, we expect that the proposed clustering method may have a significant impact on both exact and approximate solutions of Dec-POMDPs.

Dynamic Sensor Selection in Camera Networks: we presented a decision-theoretic approach to dynamic sensor selection, with a focus on tracking a person in a network of surveillance cameras using only a limited number of cameras simultaneously. We showed how we can model this problem as a POMDP, and how we can encode objectives such as maximizing coverage or improving localization uncertainty. We successfully implemented our techniques in a person tracking scenario with 10 cameras.

Auctioning POMDP tasks: We studied an approach to the assignment and execution of tasks in a multiagent system was presented. The motivation behind the approach was to illustrate the benefits of using auction protocols and the POMDP framework in multiagent systems. The auction protocols enable the coordination of multiple agents under stringent network operation conditions and robustness to individual agent failures. The synthesis of controllers for the execution of tasks was performed using the POMDP framework. The main difficulty of the POMDP approach is to compute a solution in an efficient manner. The combination of the two frameworks produced a solution in which the individual drawbacks are mitigated. From the synthesis of controllers using POMDP task models, the values to bid are naturally obtained from the respective expected discounted rewards.

Planning under uncertainty for sensor networks: We have been applying planning-under-uncertainty methodology such as POMDPs to networks of (visual) sensors and robots. Given the large resource demands of imaging sensors in terms of bandwidth and computing power, processing the video streams of a large number of cameras simultaneously might not be feasible. Given these resource constraints and a set of sensors, we study the problem of selecting a subset of sensors that can be active at any point in time. We focus on developing dynamic sensor selection methods, which can change the active subset of sensors over time. We model the problem of tracking a person using n cameras as a POMDP, under the constraint that only k cameras can emit observations at any point in time. We show how, by changing the POMDP's reward function, we can change the system's behavior in a straightforward manner, fulfilling the user's chosen objective. We have demonstrated our techniques on the ISRobotNet network of 10 cameras.

Furthermore, we studied a POMDP approach to active cooperative perception in network robot systems. In NRS, decision making based on incomplete and noisy perception is often crucial for successful task completion. POMDPs offer a strong mathematical framework for sequential decision making under uncertainty, explicitly modeling the imperfect sensing and actuation capabilities of the overall system. In particular, we considered the problem of how a robot should act in order to track and classify a particular target, considering both its local sensors as well as sensors present in the environment. We tackled this problem by modeling movement as well as classification actions.

Cooperative Perception and Navigation

Thesis: 2 PhD (Aamir Ahmad, Abdolkarim Pahliani), 1 MSc (João Santos)
Projects: 1 EC Project (URUS), 2 FCT (Dec-PUCS, PCMMC – starts 1 Jan 2010)

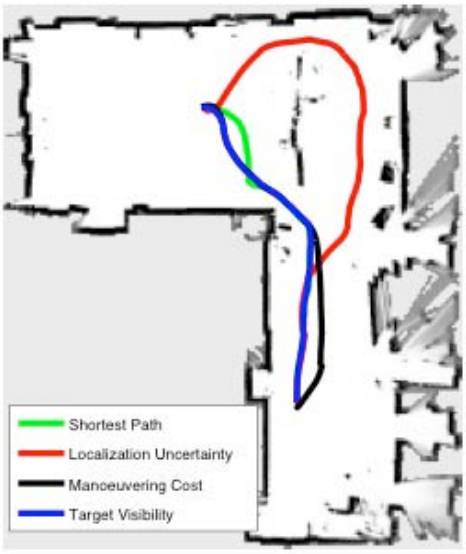
A robots team may cooperate in several forms. One of them concerns the common observation of (possibly moving) objects by the team, so as to reduce the uncertainty of the estimate of the object location and velocity by information fusion. One particular case occurs when the observed object is another element of the team. In this case, one refers to cooperative navigation. These two lines of research have been developed in this period.

Active Cooperative Perception: 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 information can be used by a robot to choose its actions, as well as providing 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, for instance in which we prioritize the tracking of certain objects. In particular, POMDPs inherently trade off task completion and information gathering.

Cooperative navigation: we have addressed the problem of path planning for a team of robots in a Networked Robot System equipped with a network of surveillance cameras as the optimization of a reward function including a set of navigation criteria, such as traversing the shortest path, the most informative path (i.e., the one for which the robot is visible the largest period of time by cameras that can help reducing its localization uncertainty), the path with less maneuvering or the past that makes the goal visible more quickly. A Markov Decision Process framework is used to model the problem, where the criteria are translated into costs and rewards.



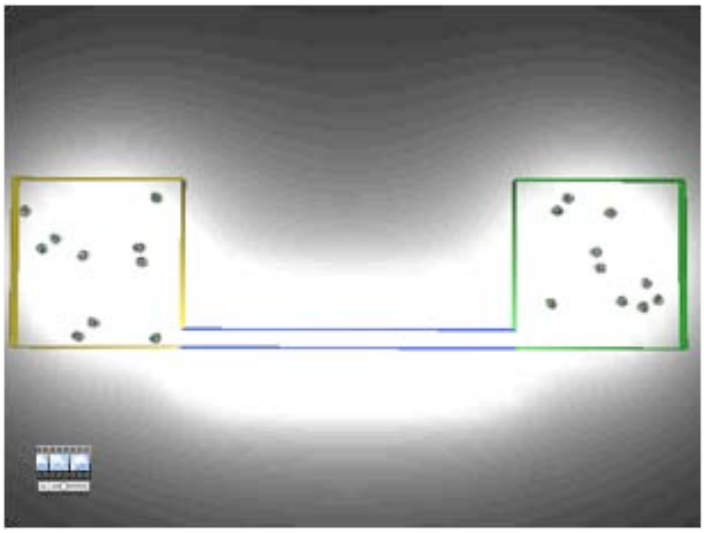
Human-Robot Interaction

1 PostDoc involved (Porfírio Silva)
Thesis: 2 PhD (Valdinei Silva, José N. Pereira)
Projects: 1 ISR Projects (Institutional Robotics)

Distinct lines of research have been pursued under this topic.
Agent programming by preference elicitation under evaluations over observed behaviours: the use of preference elicitation in computational systems helps to improve the delegation of task execution to computer agents, enabling lay people to program easily a computer agent with their own preference. The preference of a person (user) is elicited through his answers to specific questions, that the agent formulates by itself. The structure and context of the questions have been pointed as sources of variance regarding the user's answers, and such variance can jeopardize the feasibility of preference elicitation. In Valdinei Silva's PhD thesis we attempt attempt to avoid such variance is asking an user to choose between two behaviours that were observed by himself. Evaluating relatively observed behaviours turn questions more transparent and simpler for the user, decreasing the variance effect, but it might not be easier interpreting such evaluations. If divergences between agent's and user's perceptions occur, the agent may not be able to learn the user's preference. Evaluations are generated regarding user's perception, but all an agent can do is to relate such evaluation to his own perception. Another issue is that questions, which are exposed to the user through

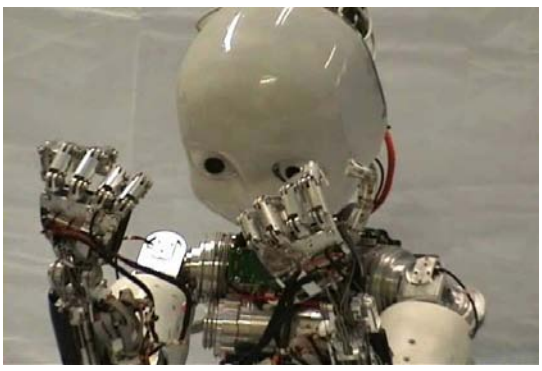
behaviours, are now constrained by the environment dynamics and a behaviour cannot be chosen arbitrarily, but the behaviour must be feasible and a policy must be executed in order to achieve that behaviour. Whereas the first issue influences the inference regarding user's evaluation, the second problem influences how fast and accurate the learning process can be made. The thesis proposes the problem of preference elicitation under evaluations over observed behaviours using the Markov Decision Process framework and theoretical properties of such framework are developed in order to turn the problem computationally feasible. The problem o different perceptions is analysed and constraint solutions are developed. The problem of demonstrating a behaviour is considered under the formulation of questions based on stationary policies and non-stationary policies. Both types of questions were implemented and tested to solve the preference elicitation in a scenario with constraint conditions.

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 behaviour 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. 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 accepted for publication. The paper concudes 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.



Cognitive architectures

Thesis: 1 PhD (Bruno Nery), 2 MSc (Carlos Neves, Rodrigo Brito)
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.

Health Care Management

Thesis: 1 MSc (Sónia Cabrita)
Projects: 1 Health Ministry Project (Concepção, Planeamento e Controlo de Processos Operacionais em Unidades de Saúde Familiar)

Partially funded by the Health Ministry and ISR, the work conducted aims at identifying interesting research topics in Health Care Management. The first project, which is ongoing and started in the beginning of 2008, intends to model Family Health Clinics.

During the last four years, in the context of the Portuguese National Health Service, there has been a significant change in the way Primary Care is provided. Aside the usual Public Health Centers (PHC), a new structure is being put in place, denominated as Family Health Units (FHU). Each FHU is composed by a maximum of 10 doctors, 10 nurses, and 7 administrative assistants, where each family enrolled in a given unit is usually assigned to a specific doctor and nurse. A FHU possesses a higher degree of autonomy and incentives than the older PHC. The standard hours of operation of a FHU are from 8:00 AM to 8:00 PM, ensuring that there is always, at least, one doctor available and trying to ensure also that any user in need of an urgent consultation will be seen by some doctor, even if it is not his/her family doctor, as the FHU may choose to provide doctor substitution for some types of appointments.

One of the challenges faced by these FHU, consists in (1) deciding the variety of services to provide and how many hours to allocate to each one of them, as well as what is the allocated duration for each service. By variety of services, or typologies, we mean, taking doctors' appointments as an example, Diabetes, Women's Health, Children's Health, House Visits, General Adult and Family, Same Day Consultation, etc. This decision also entails deciding if the doctors' agenda is free for any typology, or if each single typology is to be offered in pre-defined blocks of time, or something in between these two extremes.

Once the variety and total hours per type have been decided, the next problem that needs to be addressed is (2) what type of regulation mechanisms to implement for the access of the users to the offered services. That is, do they have to schedule an appointment in advance or can they just walk in? If they have to schedule, how far ahead are they allowed to do it? Should the access policy be different when the scheduling initiative is taken by a professional (doctor/nurse) or by a user?

We call the combination of these two problems the Offer Dimensioning Problem (ODP).

In order to help these teams to evaluate their decisions concerning this problem we developed a simulator, using iGrafx™, where different agendas for each doctor may be defined, as well as different access policies. Once that is done, demand for doctors' appointments is generated, with parameters estimated from the FHU's database, containing an historic of all appointments for some time period, and a series of statistics is

produced and collected. These will then provide a basis to support changes in the dimensioning of the agendas and in the access policies.

1.2.2 Computer and Robot Vision

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.

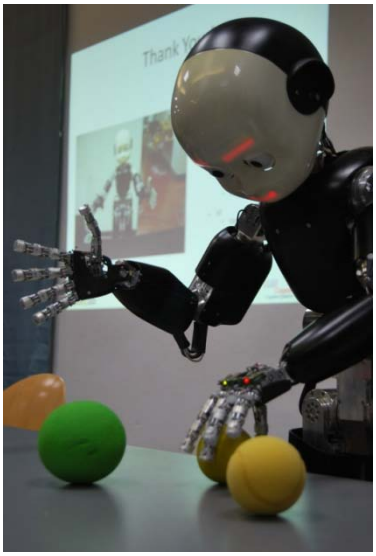
Computer vision and image analysis can thus enable a large number of applications, like 3D reconstruction, motion analysis, video surveillance and robotics, to name just a few. In addition, the massive deployment and cost reduction of cameras and the availability of low-cost, powerful processors have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

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 Mobile Robotics

The objective of the Mobile Robotics Laboratory (MRLab) is to undertake research in the area of mobile robotics, with emphasis on the navigation of single and multi-robot systems in networked environments, robot design, and human-robot interaction. Our research is often driven by a broad range of applications, and combines theoretical and implementation issues with the design and assembly of real robots.

The navigation of mobile robots is addressed in structured and unstructured environments. Surveillance and transportation applications provide the context and motivation in both single and multiple robot scenarios. These are problems requiring the integration of multiple techniques, ranging from path planning and trajectory following, environment localization and mapping to high level supervision and decision making and architectures to integrate different components. Standard (EKF and Covariance Intersection) techniques are used for localization and mapping. Robot control is addressed using inclusion systems to model behaviours. High level supervision is supported on market and POMDP based systems.

Human-Robot Interaction is the external layer that encapsulates all other subsystems in a robot. It is likely that using human-based models, with formal descriptions of concepts that have been intensively studied in social sciences, will foster the development of social robots. The focus of our research is the mathematical modeling of human interactions and the extensions to the modeling of human-robot and robot-robot interactions. Semantics is extensively used by humans and provides a typical example of such key concepts as it contains the mechanism for robots to engage socially with non-expert humans. Hybrid systems and non-smooth calculus provide the main tools for modeling and analysis.

Applications, with robot or product development, include monitoring in hazardous/remote environments with a tele-operated robot, and Air Transfer System path planning and path following definition for ITER-International Thermonuclear Experimental Reactor.

MRLab collaborates with the ISLab ans VisLab within the framework of the Associate Laboratory Theme B, including the participation in the EU project URUS on networked robotics, and projects ITER TCS/ATS and DecPUCS and with ISLab.

Collaborations outside the academic environment may foster the scientific potential of most of the techniques currently being addressed at MRLab, namely in urban robotics and networked robotics. A protocol between IST and Lisboa E-Nova (the municipal agency that handles environmental issue in Lisbon) promoted by MRLab staff is currently active. Joint project proposals may improve the visibility of the work developed at MRLab and also at ISLab and VisLab.

1.2.4 Signal and Image Processing

Sensor Networks
Distributed Detection and Estimation in Sensor Networks
Large-Scale Distributed Optimization

Optimization on Riemannian Manifolds

Wireless Communications

Space-frequency code design for noncoherent MIMO-OFDM, Space-frequency code design for noncoherent single carrier MIMO, space-time codes for spread systems, localization problem in sensor networks

Underwater communications

Computer Vision, 3D reconstruction
Bilinear Factorization Methods for Computer Vision

Medical Imaging, Ultrasound and Magnetic Resonance Imaging (MRI)
Functional Magnetic Resonance Imaging, fMRI
Medical Signal Processing
Physiological modeling

SiPLAB at UAlg is a research group with its own computer facilities and underwater acoustic equipment, hosted at the University of Algarve, which is a part of the Signal Processing Laboratory of ISR. SiPLAB at UAlg consists of a group of University professors, researchers and students interested in signal processing, underwater acoustics and communications. It currently hosts 4 permanent members, 2 research scientists, 4 Ph.D. students, 2 Ms.C. students and 3 system engineers.

VisLab at UAlg concentrates on biologically plausible models of the human visual system, i.e., multi-scale image representations derived from cells in the visual cortex, with applications to pattern recognition. The main achievement is the development of an integrated model for invariant object categorization and recognition in which keypoints are used to dynamically route line/edge codes of unnormalized input objects in cortical area V1 to the codes of normalized object templates in memory (prefrontal cortex). This model was published in Cognitive Processing. Currently VisLab at UAlg is working on multi-scale keypoint annotation for solving the correspondence problem in stereo (disparity) and motion (optical flow). In addition, the cortical model for object categorization and recognition will be extended by models for local and global gist vision, i.e., extremely fast recognition of the gist of an entire scene and first estimates of possible objects therein for solving the object-segregation problem, by integrating boundaries and surface features from motion, disparity, color and texture. The integrated models will be demonstrated on an autonomous robot which only employs a stereo camera and no other sensors.

1.2.5 Evolutionary Systems and Biomedical Engineering

The research work of this group focus on biologically inspired new algorithms and paradigms for search and optimization. Current focus is on Evolutionary Algorithms for Dynamic Environments and Artificial Life Modelling and Simulations of Bio-systems.

Biomedical signal and imaging processing algorithms and applications have been a sustained interest of the past few years. The potential of the results have been demonstrated in applications. A few recent results will be presented below:

Bio-inspired Search and Optimization on Dynamic Problems
This line of research is focused on approaches inspired by natural systems in order to develop new techniques and improve not only standard Evolutionary Algorithms on dynamic optimization problems, but also other diversity maintenance strategies that are being proposed by the scientific community. In addition (and this is an important issue), it is possible to build those schemes by relying on a self-adjustable behavior, without increasing the algorithms' complexity — it is hard to evaluate the pay-off of using a novel technique if the parameter space grows. Finally, it is hoped that this work also sheds some light on the behavior of traditional Evolutionary Algorithms on dynamic environments, namely on how their performance reacts to different parameter settings. It is shown, for instance, that standard GAs may work better than it is believed, when compared to state-of-the-art proposals, if the parameters are properly tuned. Moreover, two of the typical Evolutionary Algorithms' parameters population size and mutation probability are shown to deeply affect the algorithms' performance. Only after understanding the full extent of Evolutionary Algorithms' efficiency on

dynamic environments, it is possible to design alternative schemes that can improve their performance on significant number of problems and dynamics.

Peripheral Vision
This research line aims to study the Peripheral Vision for application purpose, namely for high competition athletes and heavy machine operators. The starting point is the development of a comprehensive index for the pure and scanning peripheral visions and ultimately a methodology or training for improvement.

Neuro-Feedback and Cognitive Tests
This line of research is focused on development of computational application for Cognitive tests and Neuro-feedback systems inspired by Brain Computer Interface and the enhancement of different cognitive activities by trimming the brain plasticity features. Biomedical applications namely in the psychiatric and neurologic disorders are thought. On the cognitive side we aim the short term memory function, concentration and precision tasks.

Micro-events paradigm for human sleep
This line of research is focused on development of a new paradigm for human sleep EEG decomposition in micro events able to describe with higher details the sleep process in physiologically significative terms.

Parallel and distributed implementation of Agent Based Systems
This line of research is focused on development of middleware for ABS over CUDA and OPEN CL for GPU and CELL based systems. Main target is LAIS II for large scale ABS simulation of biological processes.

1.2.6 Dynamical Systems and Ocean Robotics

Objectives

The key objectives of the DSORL are to meet some of the challenges in advanced robotic vehicle systems design and control and contribute to the development of faster, cheaper, and far more efficient methods and tools for ocean exploration and exploitation. 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 issues, as well as issues related to the interplay between marine sciences and marine technology. 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.

The following objectives are worth emphasizing:

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 Systems for autonomous vehicles. Study of advanced solutions focusing on the: i) development of highly performing, 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. Problems addressed: i) Motion control of autonomous vehicles; ii) Visual servoing control; iii) Path Following; iv) Terrain Contour Tracking; v) Coordinated/cooperative control of groups of autonomous vehicles; vi) Networked control over faulty communication links.

E. Development of advanced methods for Cooperative 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 Craft (ASC) and Unmanned Aerial Vehicles (UAVs) and 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.

C. Tests and scientific missions with the robots developed in cooperation with the scientific partners of the ISR Associated Laboratory and other international institutions.

Main Achievements

Theoretical landmarks

1. Further Advances in the formulation of a Robust Multiple-Model Adaptive Control (RMMAC) architecture for linear time-invariant and time-varying plants subjected to structured and unstructured uncertainty. Work was also done to assess the performance that can be achieved with open-loop unstable plants.

2. Derivation of multiple model adaptive estimation (MMAE) and model identification methods that rely on a minimum energy criterion.

3. Development of a new methodology for multiple vehicle cooperative path planning under temporal and energy expenditure constraints, with due account for temporal or spatial deconfliction requirements.

4. Development of a general framework for multiple vehicle time-coordinated path following control in the presence of communication failures.

5. Study and assessment in simulation of the efficacy of a set of algorithms for cooperative motion control of multiple autonomous marine vehicles 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. Study and assessment (in simulation and through tests at sea) of marine vehicle path following systems using inner-outer loop control structures.

8. 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.

9. Study of single beacon acoustic navigation systems for AUVs in the presence of unknown ocean currents. The proposed solution has innovative contributions on: i) necessary and sufficient conditions on the observability of the system are derived that can be used for the motion planning and control of the agent; ii) a linear model is developed that mimics the exact dynamics of the nonlinear range-based system, and a Kalman filter is applied to estimate the position of the source, as well as the difference between the agent and the source drift velocities.

10. Improvement of the capabilities of "$\text{NetMar}_{\text{SyS}}$: A Networked Marine Systems Simulator for Hardware-In-The-Loop Testing of Cooperative Multiple Vehicle Control and Navigation Systems". $\text{NetMar}_{\text{SyS}}$ is MATALAB/SIMULINK-based software suite developed at IST/ISR for the simulation of different types of cooperative missions involving a variable number of heterogeneous marine craft, with due account for its dynamics. $\text{NetMar}_{\text{SyS}}$ grew out of the practical need to assess the performance of advanced cooperative and navigation control algorithms, prior to system implementation and testing at sea. The kernel of $\text{NetMar}_{\text{SyS}}$ was first developed in the scope of the EU GREX project. The simulation underwent substantial revision and expansion in the course of the EU CO^3AUVs project.

11. Further development and experimental evaluation, using the Catamaran DELFIMx, of a low cost Inertial navigation System (INS) based on asymptotically stable discrete-time nonlinear complementary filters that merge inertial measurements with Earth's magnetic field observations and GPS data.

12. Study of filtering structures for USBL tightly coupled inertial navigation. Development of nonlinear GPS/IMU based observers for rigid body attitude and position estimation. Study of estimators on SE(3) using range-only measurements Development and practical evaluation of acoustics-based systems for underwater vehicle positioning and tracking. Estimation algorithms were derived and their performance tested during real missions at sea.

13. Development of the so called Stability Overlay (SO) for linear and nonlinear time-varying plants, that provides input/output stability guarantees for a wide set of adaptive control schemes. This methodology endows the Multiple-Model Adaptive Control (MMAC) architectures with robust stability properties when the plant to be controlled is uncertain and time-varying.

14. Development of a multiple-model adaptive control methodology, using set-valued observers (MMAC-SVO) for the identification subsystem, that is able to provide robust stability and performance guarantees for the closed-loop, when the plant, which can be open-loop stable or unstable, has significant parametric uncertainty.

15. Rotorcraft path following control for extended flight envelope coverage - The proposed solution consists of a nonlinear state feedback controller for thrust and torque actuations combined with a path following timing law that i) guarantees global asymptotic convergence of the path following error to zero, for a large class of

three-dimensional paths, ii) ensures that the actuation does not grow unbounded as function of the position errors, and iii) allows for zero thrust actuation to be applied when the vehicle is converging to the path.

16. Combination of Lyapunov Functions and Density Functions for Stability of Rotational Motion - Lyapunov methods and density functions provide dual characterizations of the solutions of a nonlinear dynamic system. This work exploits the idea of combining both techniques, to yield stability results that are valid for almost all the solutions of the system. Based on the combination of Lyapunov and density functions, analysis methods are proposed for the derivation of almost input-to-state stability, and of almost global stability in nonlinear systems.

17. Nonlinear Attitude Estimation Using Active Vision and Inertial Measurements – This topic considers the problem of estimating the attitude of a rigid body equipped with a triad of rate gyros and a pan and tilt camera. The nonlinear attitude observer integrates angular velocity measurements from rate gyros, with images of a planar scene provided by the camera. By exploiting directly sensor information, i) a stabilizing feedback law is introduced and exponential convergence to the origin of the estimation errors is shown; ii) an active vision system is proposed that relies on an image-based exponentially input-to-state stable (ISS) control law for the camera pan and tilt angular rates to keep the features in the image plane.

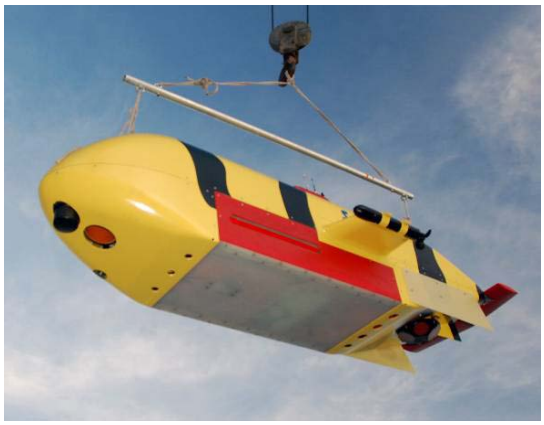
18. Control of Impulsive Renewal Systems: Application to Direct Design in Networked Control – This work considers the control of impulsive systems with independent and identically distributed intervals between jumps. The control action and output measurement are assumed to take place only at jump times. We give necessary and sufficient conditions, in the form of LMIs, for mean square stabilizability and detectability and solve an infinite horizon quadratic optimal control problem, under appropriate stabilizability and detectability properties of the system. The class of systems considered is especially suited to model networked control systems utilizing CSMA-type protocols, with stochastic intervals between transmissions and packet drops.

19. Sensor-Based Complementary Globally Asymptotically Stable Filters for Attitude Estimation - This work addresses the design, analysis, and performance evaluation of a new class of globally asymptotically stable filters for attitude estimation. The design is based directly on the sensor measurements as opposed to traditional solutions that resort to parameterizations of the attitude, e.g., Euler angles, quaternions, or rotation matrices, and therefore it does not have problems such as singularities, unwinding phenomena, or topological limitations for achieving global asymptotic stability. The proposed solution includes the estimation of gyros biases, incomplete sensor measurements, systematic tuning procedures, and also allows for the inclusion of frequency weights to model colored noise on the different sensing devices. Finally, and due to the inherent structure, the filters are complementary.

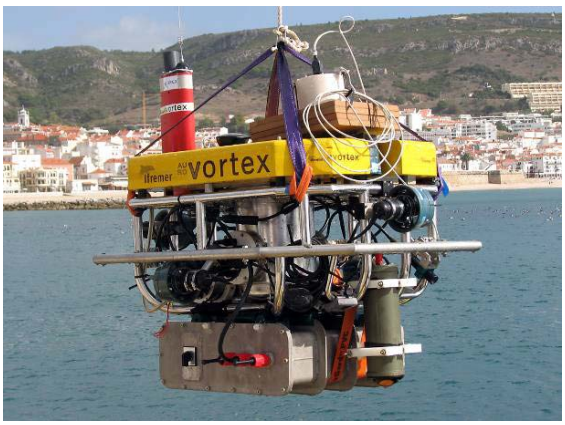
Practical Achievements

1. Full system development, implementation, and demonstration of the operational capabilities of the DELFIM and DELFIMx autonomous surface vehicles (ASV) that are property of ISR/IST.

2. Demonstration of cooperative vehicle motion control with four autonomous marine robots in the scope of the EU GREX project: the DELFIM and DELFIMx ASVs, and the SeeBee and VORTEX AUVs that are property of ATLAS and IFREMER, respectively. The core of the final tests of the EU GREX project took place in Sesimbra, Portugal from October 26 to November 6, 2009 with the participation of all project partners and the joint coordination of ISR/IST and the IMAR/DOP/UAzores.



The SeaBee AUV (ATLAS)



The Vortex AUV (IFREMER)

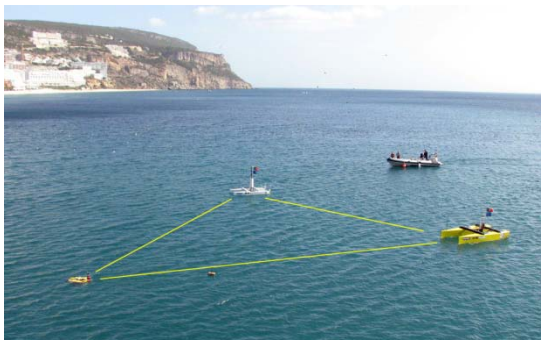
The DELFIM ASV (ISR/IST)

The DELFIMx ASV (ISR/IST)

Marine Robots used in the scope of the EU GREX project: deployment in Sesimbra, PT

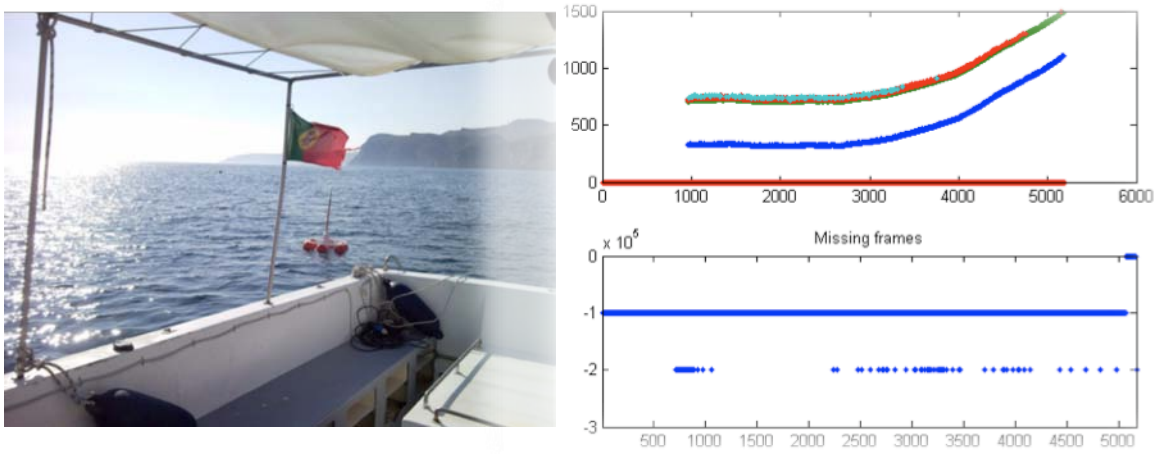
The tests were instrumental in showing the efficacy of the systems developed for cooperative mission planning and programming, followed my mission execution at sea with heterogeneous robots from different partners. The missions executed included cooperative path following with multiples vehicles and different geometrical formations, as well as cooperative target tracking. In the latter situation, the vehicles were tracked a moving target underwater that broadcast its position via an acoustic communications system. The experience acquired in the scope of the project paves the way for the development of a new breed of systems for cooperative motion control.

Execution of Cooperative Path Following (CPF) with four vehicles: the Mission Console with the actual vehicles in the background.



Successful execution of CPF with 3 vehicles in a triangle formation.

3. Demonstration at sea of a retrofitted version of the GPS Intelligent Buoys System, under the framework of the RUMOS project. The figure below shows the support vessel used, together with one of the buoys. Recorded data are also shown.



4. Design, development, and test of an integrated Ultra Short Baseline (USBL) and Inertial Navigation System (INS) to be used as a low cost navigation system for underwater robotic vehicles. An architecture for the open prototype was proposed, the acoustic array design and calibration discussed, the inertial sensors package selected, and the supporting acoustic signals studied. Preliminary sea tests were conducted in the Azores, under the framework of the RUMOS project. The performance of the acoustic positioning system obtained, using namely Direct Sequence Spread Spectrum (DSSS) coded signals, was validated. The next figure shows the acoustic array and the processing electronics in a marinized container.

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 2009, under the supervision of ISR members.

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 Systems Lab
Project partners: Instituto Superior Técnico (IST)
Initiated: 1997
Expected conclusion: N/A
Classification: N/A

♦

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 2009 we obtained the following results. 1) This paper introduced a method for lossless clustering of action-observation histories in Dec-POMDPs, which can be applied in GMAA∗ policy search for Dec-POMDPs via Bayesian games. Empirical evaluation of GMAA∗ demonstrated that for several domains speedups of multiple orders of magnitude are achieved by clustering. We expect that the proposed clustering method may have a significant impact on both exact and approximate solutions of Dec-POMDPs. 2) We combined task auctions, a popular method for creating loosely coupled cooperation in multirobot systems, with POMDP task models. The combination of the two frameworks produced a solution in which the individual drawbacks are mitigated. From the synthesis of controllers using POMDP task models, the values to bid are naturally obtained from the

respective expected discounted rewards. 3) We worked on an intelligent assistant based on factored MDPs that provides power plant operators with useful recommendations. We explained the formalism of factored Markov decision processes and a intuitive algorithm to approximate decision models based on training data.

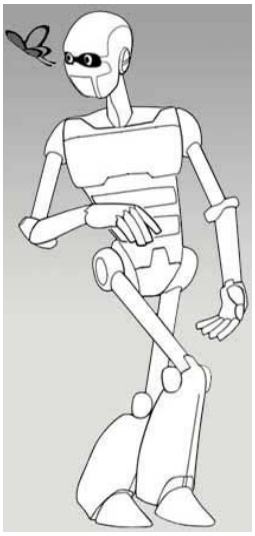
Research Areas: Planning under uncertainty, POMDPs
Laboratories: Intelligent Systems Lab
Project partners: Instituto Superior Técnico (IST)
Initiated: Oct. 2007
Expected conclusion: Sept. 2010
Classification: PTDC/EEA-ACR/73266/2006

♦

Project Name: ROBOSOM – A Robotic Sense of Movement

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

Project description: The objective of the project 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
Laboratories: Vislab - Computer Vision Lab
External Partners: IST, SSSA (I), College de France (F); Waseda University (JP).
Initiated: Dec. 2009
Expected conclusion: Nov. 2012
Classification: FP7-ICT-248366

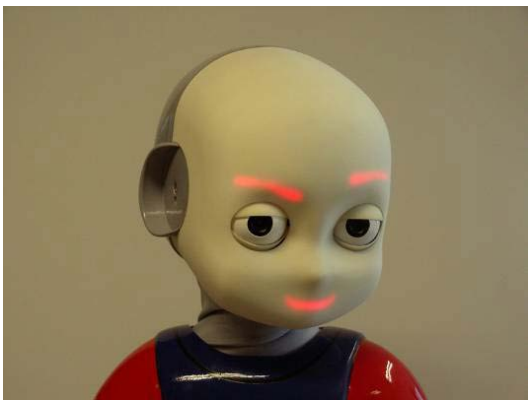
♦

Project name: ROBOT-CUB - ROBotic Open-architecture Technology for Cognition, Understanding, and Behaviour

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

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

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



Research Areas: Computer Vision
Laboratories: Vislab - Computer Vision Lab
Project Partners: IST, DIST, U.Genova (I), Arts Lab SSS. Anna (I), AI Lab U. Zurich (CH); Dpt Psychology U. Uppsala (SE); Dept Human Physiology, U. Ferrara (I); U.Hertfordshire (UK); U. Salford (UK); EPFL (CH); Telerobot S.r.l. (I); European Brain Research Institute (I)
Initiated: Sep. 2004
Expected conclusion: Jan. 2010
Classification: FP6-IST-2004-004370

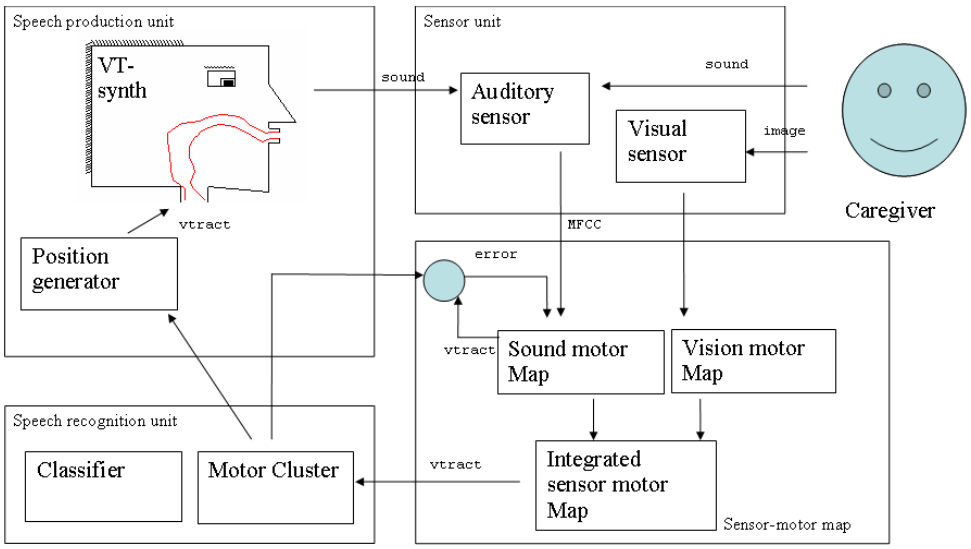
Project name: CONTACT - Learning and Development of Contextual Action

Project leaders within ISR: Professor José Santos–Victor and
Professor Alexandre Bernardino (I ST/ISR)

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

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

We developed an architecture that allows an artificial system to acquire language. Initially the system explores its own vocal track and builds audiomotor maps. Then, through the interaction with a caretaker the system learns basic sounds (e.g. phonemes) that can later on be used for communication.



Research Areas: Computer Vision
Laboratories: Vislab - Computer Vision Lab
Project Partners: IST, DIST, U.Genova (I), Dpt Psychology U. Uppsala (SE); Dept Human Physiology, U. Ferrara (I); Dpt Linguistics, U. Stockholm (SE);
Initiated: Sep. 2005
Conclusion: Aug. 2009
Classification: FP6-NEST-5010

Project name: BIO-LOOK - Biomimetic Oculomotor Control for Humanoid Robots.

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

Project description: There is an increasing interest in advanced human-robot interfaces e.g. for "service robots" able to perform a variety of assistive tasks in human inhabited environments. Head and eye movements are particularly important for human-humanoid interaction, because they constitute a highly attended and communicative part of the human body, being able to convey emotions and express intentions and goals. On one hand, the way a robot controls its gaze toward targets may elicit different emotional interpretations by the user. Fast motions may indicate deep engagement on a task in time-critical or dangerous situations while smooth motions may indicate idleness and availability for interaction. On the other hand, the visual locations in which a robot concentrates its attention convey information about objects and spatial locations of interest to the current task, driving users' attention to the important items in the scene (sharing attention). By concentrating the direction of observation in particular objects or humans will indicate if the robot is enrolled in a well defined task or its intention to interact with the human. Both modalities constitute basic implicit communication skills that will contribute to the development of advanced human-humanoid interfaces.

This project will address the following topics in oculomotor control: (i) how to perform human-like eye-head movements and postures while executing tasks and interacting with humans; (ii) how are oculomotor processes learned and developed through childhood; (iii) how can robot behaviour be modulated to implicitly communicate emotions, intentions and goals to human users. The studied methodologies will be implemented and tested both in realistic dynamical simulations and in prototype humanoid robotic platforms available in the consortium.

Research Areas: Computer Vision, Learning, Oculomotor Control
Laboratories: Vislab - Computer Vision Lab
Project Partners: University of Uppsala (Sweden)
Initiated: Oct. 2007
Expected conclusion: Sep. 2010
Classification: FCT - PTDC/EEA-ACR/71032/2006

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Project name: MMCACC - Modern Monte Carlo Algorithms for Computational Control

Project leader within ISR: Dr. Luis Montesano (IST/ISR)

Project description: Reasoning and making decisions under uncertainty appears in numerous applications ranging from standard process control (chemical process control) to robotics (designing robots exploring optimally their unknown environment), sensor networks and tracking (positioning optimally sensors so as to optimize the received information) or finance (option pricing). Such problems are also closely related to experimental design (clinical trials) and active learning (exploring intelligently massive multimedia databases for information retrieval). Despite the growing interest in such problems, there is currently no generic computational algorithm available for complex stochastic models. Closed form or exact solutions only exist for very simple models, as the linear Gaussian case and for discrete world problems. In order to deal with continuous spaces, researchers have proposed numerous approximations. Unfortunately, most of them still rely in Gaussian approximations or have been developed for very specific applications.

The objective of this project is to develop modern Monte Carlo methods to solve discrete time stochastic optimal control problems in both the fully and partially observed cases for nonlinear and/or non-Gaussian models. It aims to combine modern computational tools developed actively in statistics (Markov chain Monte Carlo, Sequential Monte Carlo aka Particle filters) to ideas developed in automatic control, operation research (gradient estimation) and reinforcement learning (value function and policy parameterization). The focus is in developing generic algorithms that can be applied in different domains and provide a unified framework for this type of problems.

Research Areas: Reasoning under uncertainty, Monte Carlo Algorithms, Partially Observed Markov Decision Processes, Robotics
Laboratories: Vislab - Computer Vision Lab
Project Partners: University of British Columbia (CA)
Initiated: Sept. 2007
Expected conclusion: Aug. 2010
Classification: FCT - PTDC/EEA-ACR/70174/2006

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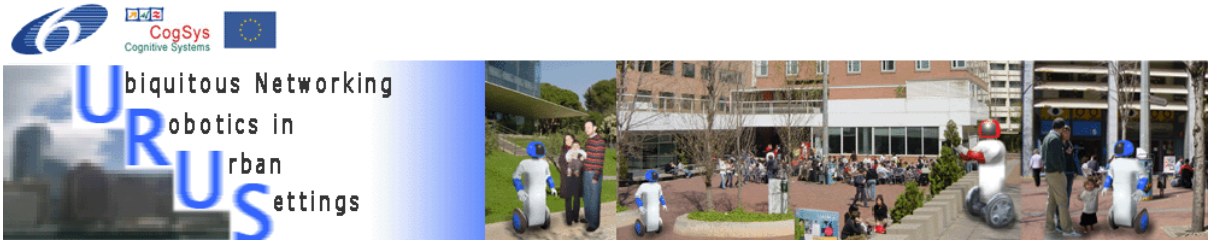
Project name: **URUS-** Ubiquitous Networking Robotics in Urban Settings



Project leaders within ISR: Profs. João Sequeira and José Santos-Victor (IST/ISR)

Project description: The general objective of the URUS project was the development of new ways for the cooperation between network robots and human beings and/or the environment in urban areas, in order to achieve efficiently tasks that for single systems would be too complex, time consuming or costly. For instance, the cooperation between robots and video cameras can solve surveillance problems for blind spots in urban areas, or the cooperation between robots and wireless communications devices can improve efficiency in people assistance services. The focus of the project is in urban pedestrian areas, for which there exists a growing interest in reducing the number of cars and improving the quality of life. Network robots become an important instrument towards these goals.

Networked robots are a new concept that integrates robots, sensors, communications and mobile devices in a cooperative way. Meaning that, not only a physical connection between these elements exists, but also, that there is a need for the development of novel intelligent cooperation methods for task oriented purposes, new ways of communication between the different elements, and new robot mobility methods using the ubiquity of sensors and robots. The URUS project is focused on designing and developing a network of robots that in a cooperative way interact with human beings and the environment for tasks of guidance and assistance, transportation of goods, and surveillance in urban areas. Specifically, our objective has been the design and development of a networked robot architecture that integrates cooperating urban robots, intelligent sensors (video cameras, acoustic sensors, etc.), intelligent devices (PDA, mobile telephones, etc.) and communications. The main scientific and technological challenges that have been addressed during the course of the project are: navigation and motion coordination among robots; cooperative environment perception; cooperative

map building and updating; task negotiation within cooperative systems; human robot interaction; and wireless communication strategies between users (through mobile phones, PDAs), the environment (cameras, acoustic sensors, etc.), and the robots.

Two demonstration scenarios in the Barcelona Robot Lab, a [10,000]m2 area devoted to urban robotics experimentation (Fig. **1**). Scenario 1 involves transporting a person or goods to a destination; and Scenario 2 is devoted to drive people slowly and orderly towards the main exit in public spaces at closing hour. In the first case, a person asks, by means of a mobile phone, for a robot in order to receive the service. The robot that has the transport functionality, is available and closest to that person, approaches the person, identifies the person, and guides him or her to the requested final destination. The distributed sensor network provides information for the tasks of localization, identification, guidance, and robot navigation. In the second case, the trigger signal for the surveillance service of public space is the closing time or a human gesture. Then, the appropriate robots available for this service approach the area where people is to be gathered and directs them to leave the space.

Fig. 1- *Several views of the Barcelona Robot Lab (UPC Campus Nord) test site used in URUS*

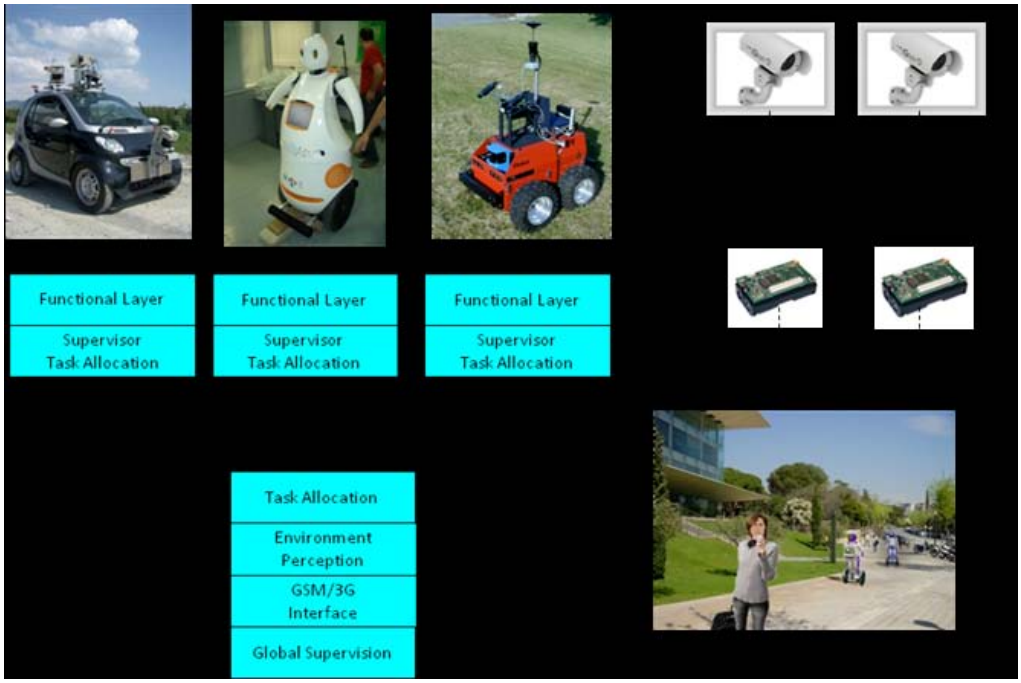


Fig. 2- *URUS functional architecture*

Fig. **2** shows the functional architecture of the project along with three of the robots used. Human-robot interaction requirements were addressed both in mission design and robot design.
The individual components developed were tested at ISR-Lisbon prior its deployment at the Barcelona Robot Lab. The ISRobotNet, created in ISR-Lisbon, is an experimental setup where general purpose networked robot systems can be tested. The setup includes a network of sensors and middleware capabilities that enables reliable systems integration. MRLab and ISLab have been collaborating in the design and deployment of the middleware tool. Fig. **3** shows a view of the space where the setup is installed, the global architecture, and an example of the detection of humans moving in the area.

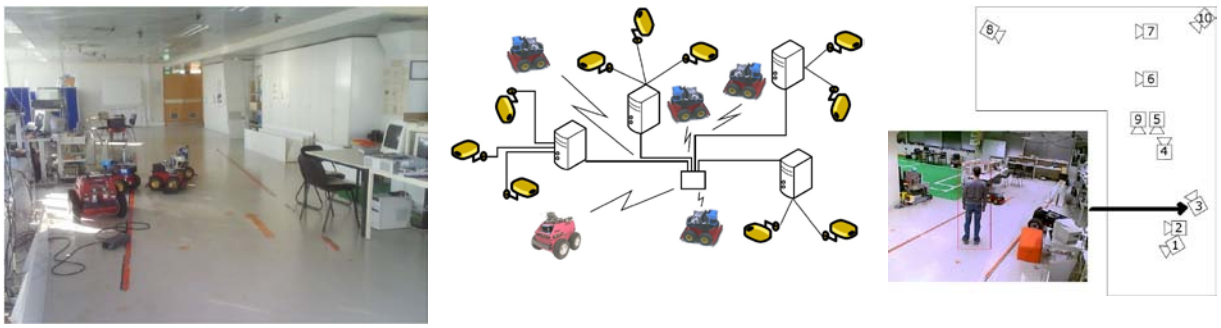


Fig. 3- *Three aspects of the ISRobotNet test site, at ISR-Lisbon*

In what concerns robot control, high level decision strategies are being addressed using economic market models. This line of work seems particularly important in multiple robot applications to yield team behaviours as natural as that of a team of humans. MRLab is currently participating in a number of project proposals intending to be the follow up of the URUS project. Moreover, MRLab proposed a collaboration protocol between IST and Lisbon city authorities to develop urban robotic systems in the same line of that developed by URUS in Barcelona. This protocol has been accepted and MRLab people is working on project proposals related to this theme.

The Vislab team at IST is responsible for the development of tools to have a robust communication interface between the network of robots and persons. The key element of the communication is the recognition of gestures that can form a simple language for humans to interact with the URUS system, and the estimation of

positioning data both for people and robots. The key human activity to be recognized is the waiving by people. The importance of this specific gesture is due to its "universal" nature: it is used as an attention triggering and emergency indicator by most people independently of their culture.

Figures 4 and 5 show two key aspects of the perception components in URUS, namely the recognition of waving gestures by people and the detection of people and robots in video images. As aforementioned, waving was selected to trigger the two types of missions considered given that it is a gesture widely accepted in social terms. Detecting people and robots provides information that can be used to improve localization estimates.

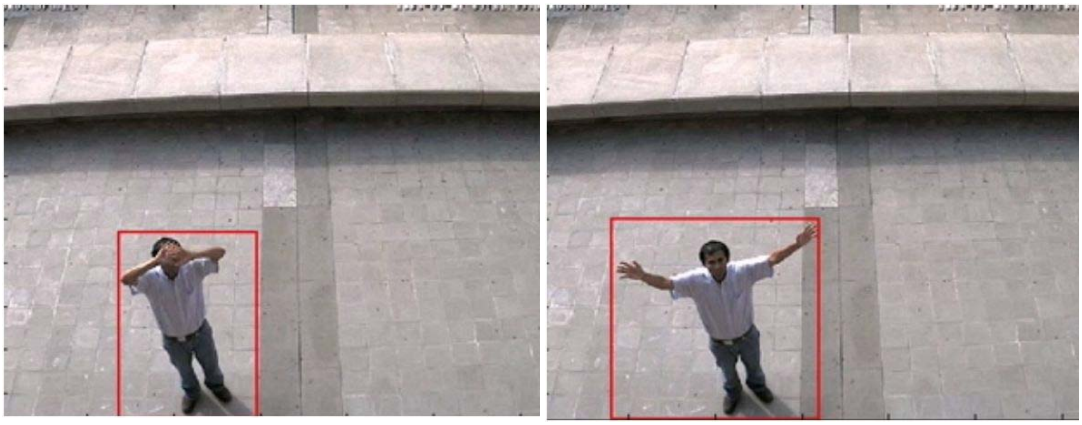


Fig. 4- *Gesture detection at the Barcelona Robot Lab*

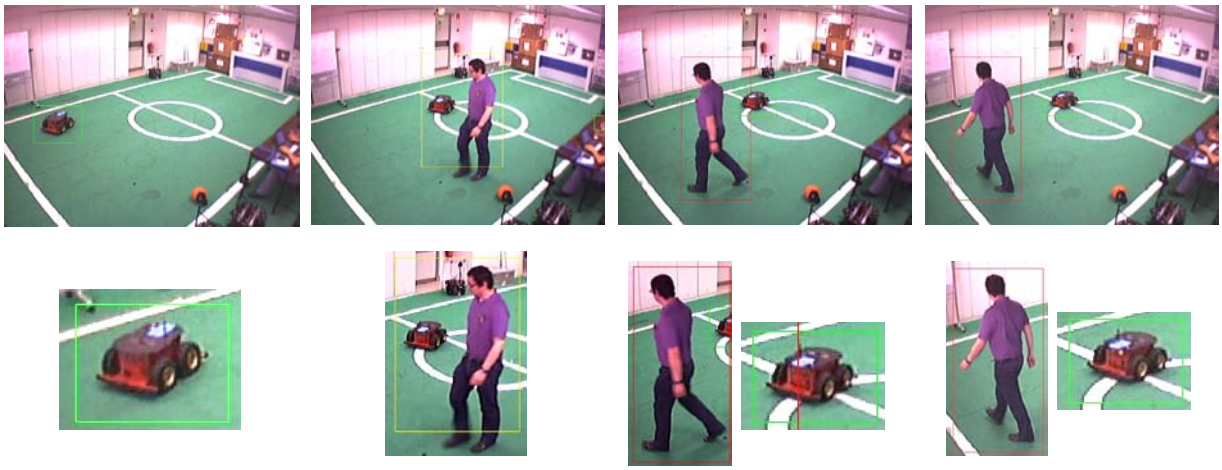


Fig. 5- *Detection of robots and people at ISRobotNet site*

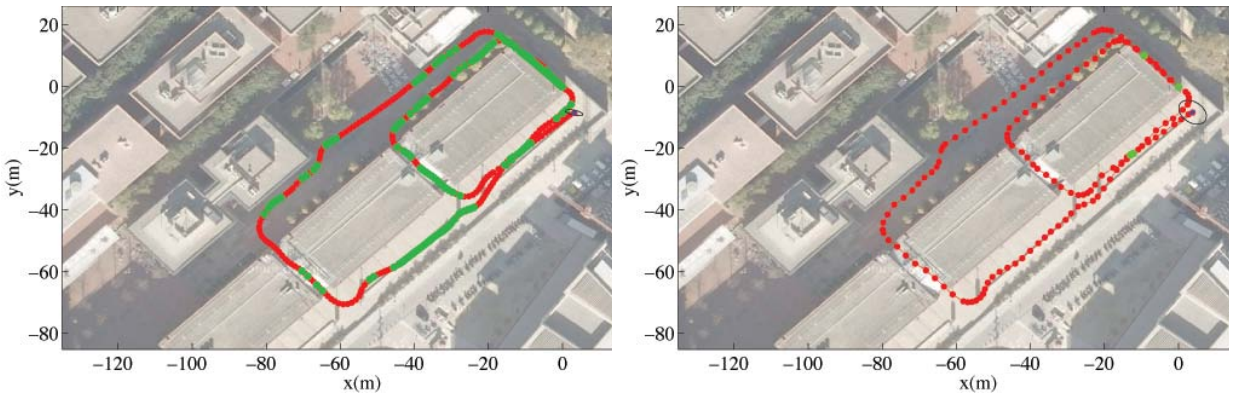


Fig. 6 - *Example of a real trajectory by one of the robots in URUS*

The robustness of the basic components is key for the success of the project. Fig. **6** shows an example of a real trajectory, performed at the Barcelona Robot Lab. It is worth to point to the quality of the localization estimates that allowed the outdoor navigation in a wide area.

Research Areas: Cooperative Robotics, Human-Robot Interaction, Navigation
Laboratories: Mobile Robotics, Computer Vision Lab, Intelligent Systems Lab
Project partners: Instituto Superior Técnico (IST), Universitat Politecnica de Catalunya (UPC), Universidad de Zaragoza (UniZar), Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna (SSSA), The University of Surrey (UniSurrey), Centre National dela Recherche Scientifique (CNRS/LAAS), Eidgenoessische Technische Hochshule Zurich (ETHZ), Robotech SRL, Telefonica Investigacion y Desarrollo SA Unipersonal, Agencia d'Ecologia Urbana de Barcelona, Associacion de la Investigacion y Cooperation Industrial de Andalucia (AICIA)
Initiated: Sept. 2006
Expected Conclusion: Nov. 2009
Classification: FP6-2005-IST-6-045062

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Project name: Activities Related To the Development of an Air Transfer System Prototype and Cask Transfer System Virtual Mock-Up

Project leaders 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.

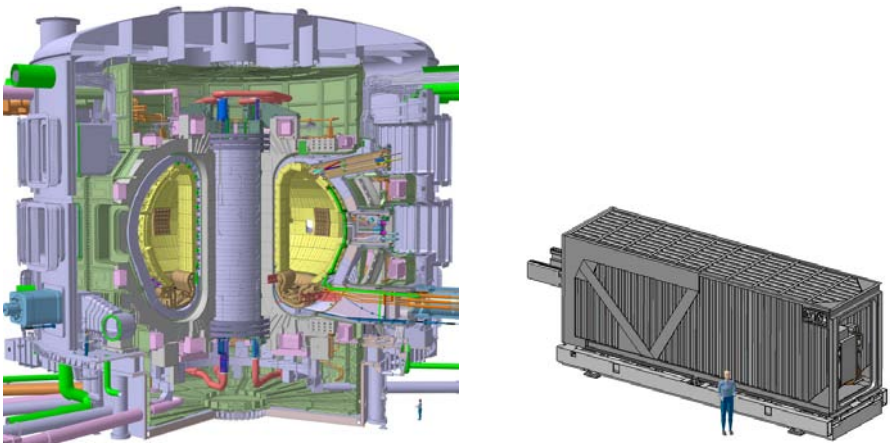

Fig.1 - left: Tokamak Building; right: Transfer Cask System

Developments and studies in the topic of path planning and trajectory following of the TCS/ATS inside the TB and HCB were performed in 2009, in the frame of the grant F4E-2008-GRT-016 (MS-RH), “Activities related to the development of an Air Transfer System prototype and Cask Transfer System Virtual Mock-up” supported F4E and 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 maneuvers and 18 with at least a maneuver), and 17 trajectories in HCB. Figure 1 represents the set of optimal trajectories and the area spanned by the TCS in the Divertor level of TB. 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. Fig. displays a trajectory in the Equatorial level of TB with two maneuvers, 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.

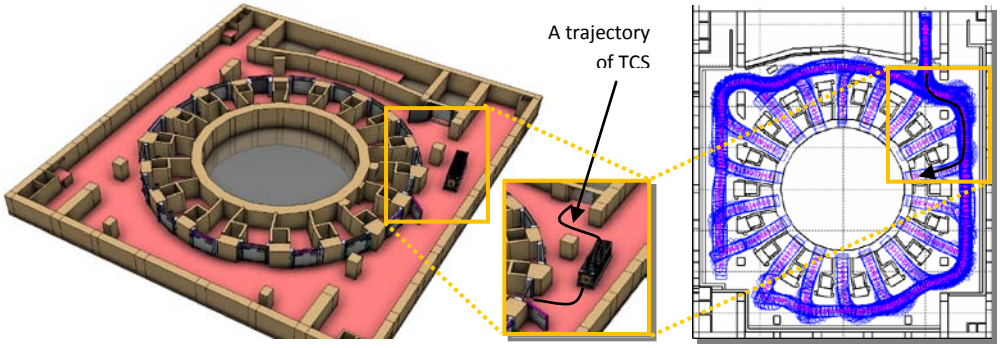

Fig. 2 - Optimal trajectories for all ports of level B1 in TB (all spanned areas were obtained with 8500 mm x 2620 mm TCS).

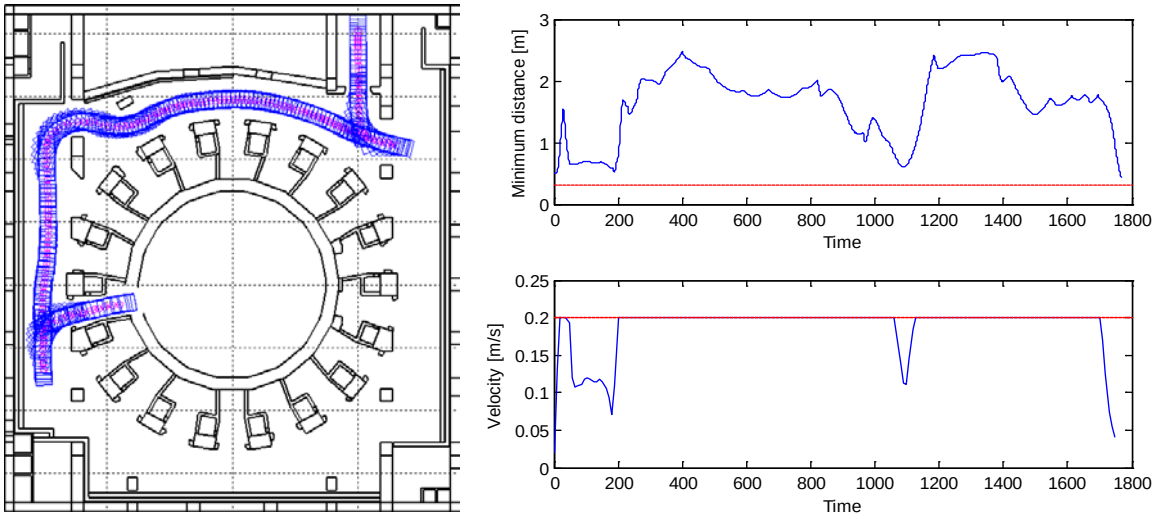

Fig. 3 - (left image) Trajectory between the lift and the vacuum vessel port cell 10 in the level B1 of Tokamak Building; and, (right image) the minimum distance between the TCS and the nearest obstacle and velocity along the trajectory.

Preliminary trajectory results obtained before the grant starting date predicted that the doors' configurations in all levels of TB might raise problems in terms of optimal and safe trajectories to/from the lift and all VV ports. These predictions were confirmed through deep studies on the three levels of TB using its latest CATIA model (March 2009). 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.

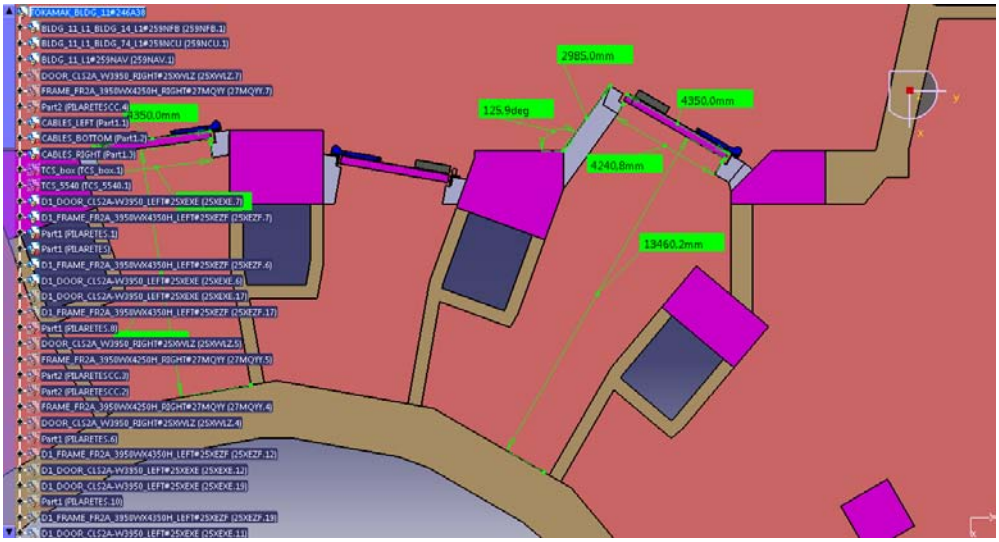

Fig. 4 - IST proposal for port extension and door configuration changes in VV port cell 8 in level L1of TB.

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.

Preliminary results on the specification of a test facility for an ATS/TCS prototype were obtained. 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 of the ATS/TCS. This will guide the specification of the building requirements.

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.

Research Areas: Cooperative Robotics, Human-Robot Interaction, Navigation
Project partners: Instituto Superior Técnico (ISR/IST and IPFN/IST)), ASTRIUM EADS (France), CIEMAT (Spain)
Laboratories: Mobile Robotics, Intelligent Systems Lab
Initiated: March 2009
Expected conclusion: June 2010
Classification: F4E-2008-GRT-016 (MS-RH)

Project name: **FREESUBNET** - Marie Curie Research Training Network

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

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.

URL: http://www.freesubnet.eu/

Research Areas: Navigation, Guidance, and Control, Acoustic Cooperative Motion Control, Underwater Positioning and Communications, Networked Control
Laboratories: Dynamical Systems and Ocean Robotics Lab, Signal and Image Processing Group, and Computer and Robot Vision Lab
Project Partners: 15 European partners
Initiated: 2006
Expected conclusion: 2010
Classification: MRTN-CT-2006-036186

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

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

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.

URL: http://robotics.jacobs-university.de/projects/Co3-AUVs/

Research Areas: Navigation, Guidance, and Control, Acoustic Cooperative Motion Control, Cognitive Robotics
Laboratories: Dynamical Systems and Ocean Robotics Lab, Signal and Image Processing Group, and Computer and Robot Vision Lab
Project Partners: GRAAL Tech SRL (IT), Instituto Superior Técnico (PT), Jacobs University Bremen, ISME (IT)
Initiated: 2009
Expected conclusion: 2012
Classification: EU-FP7-ICT-231378

Project name: **VENUS** - Virtual ExploratioN of Underwater Sites

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

Project description: The VENUS project aims at providing scientific methodologies and technological tools for the virtual exploration of deep underwater archaeology sites. Underwater archaeological sites, for example shipwrecks, offer extraordinary opportunities for archaeologists due to factors such as darkness, low temperatures and a low oxygen rate which are favourable to preservation. On the other hand, these sites cannot be experienced first hand and today are continuously jeopardised by activities such as deep trawling that destroy their surface layer. The VENUS project will improve the accessibility of underwater sites by generating thorough and exhaustive 3D records for virtual exploration.

The project team plans to survey shipwrecks at various depths and to explore advanced methods and techniques of data acquisition through autonomous or remotely operated unmanned vehicles with innovative sonar and photogrammetry equipment. Research will also cover aspects such as data processing and storage, plotting of archaeological artefacts and information system management. This work will result in a series of best practices and procedures for collecting and storing data. Further, VENUS will develop virtual reality and augmented reality tools for the visualisation of an immersive interaction with a digital model of an underwater site. The model will be made accessible online, both as an example of digital preservation and for demonstrating new facilities of exploration in a safe, cost-effective and pedagogical environment. The virtual underwater site will provide archaeologists with an improved insight into the data and the general public with simulated dives to the site.

URL: http://dsor.isr.ist.utl.pt/Projects/Venus/

Research Areas: Archaeology, Underwater technology, Virtual reality
Laboratories: Dynamical Systems and Ocean Robotics Lab, Signal and Image Processing Group, and Computer and Robot Vision Lab
Project Partners: CNANS - Portuguese Institute of Archaeology (PT), CNRS (FR), COMEX (FR), ISM - Università degli Studi di Genova (IT), IST/ISR - Instituto Superior Técnico/Institute for Systems and Robotics (PT), LFUI - Leopold-Franzens-Universität Innsbruck (AT), MCC - Department for Underwater and Undersea Archaeological Research (FR), MIBAC-SBAT - Soprintendenza Beni Archeologici della Toscana (IT), SIMVIS - University of Hull (UK), UEVE - Université d'Evry Val d'Essonne (FR), UoY-ADS University of York (UK)
Initiated: Jul. 2006
Expected conclusion: Jun. 2009
Classification: EU-FP6-IST- 034924

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Project name: **GREX** - Coordination and Control of Cooperating Heterogeneous Unmanned Systems in Uncertain Environments

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

Project Description: Due to the limitations of state-of-the-art embedded systems, marine vehicles are subjected to strict constraints in both their autonomy and capabilities. It would be a leap ahead if a researcher could use a multiple vehicle approach, whereby each vehicle plays the role of a sophisticated node (with sensor, processing, and communication capabilities) in a possibly large network - this means combining the

properties of different systems in a team.Grex - the latin word for a herd or flock - suggests the focus of the project: to create a conceptual framework and middleware to coordinate a flock of heterogeneous robotic vehicles in order to achieve a well defined practical goal in an optimised manner.

The main goal of the project is to achieve a first level of distributed "intelligence" through dependable embedded systems that are interconnected and cooperate towards the coordinated execution of tasks. Thus the project will witness the development of theoretical methods and practical tools for multiple vehicle cooperation, bridging the gap between concept and practice.The technology developed must be on one hand sufficiently generic in order to interface preexisting heterogeneous systems. On the other hand it must be sufficiently robust to cover problems caused by faulty communications. From a practical standpoint, the developments will cover methods for effective programming of multiple systems, coordinated mission control and navigation, formal methods for validation and testing of the programming languages, and the use of perception and communication techniques to enable ad hoc formation of information - and sensor-networks. A series of field trials with autonomous marine robots will be carried out to assess the efficacy of the methods developed under stringent acoustic communication constraints.

URL: http://dsor.isr.ist.utl.pt/Projects/Grex/

Research Areas: Embedded Systems, Communication Technology, Ad Hoc Networking, Unmanned, Underwater Vehicles, Cooperation, Navigation, Swarm, Flock, Maritime Research
Laboratories: Dynamical Systems and Ocean Robotics Lab, Signal and Image Processing Group, and Computer and Robot Vision Lab
Project Partners: ATLAS Elektronik (DE), IFREMER (FR), IMAR-DOP/University of the Azores (PT), INNOVA (IT), IST/ISR Instituto Superior Técnico/Institute for Systems and Robotics (PT), MC Marketing Consulting (DE), SCIANT (BG), SEEBYTE (UK), TU Ilmenau (DE)
Initiated: Jun. 2006
Expected conclusion: Jun. 2009
Classification: EU-FP6-IST-035223

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Project name: **DENO** - DEvelopment of Nonlinear Observers

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

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.

URL: http://users.isr.ist.utl.pt/~pedro/DENO

Research Areas: Nonlinear Observers; Multi-model adaptive estimators; Minimum-energy and H-infinity observers; Sensor networks
Laboratories: Dynamical Systems and Ocean Robotics Lab
Project partners: Center for Control, Dynamical-systems, and Computation - University of California Santa Barbara (USA), Instituto de Sistemas e Robótica - Universidade de Coimbra (P)
Initiated: Sep. 2007
Expected conclusion: Dec.2010
Classification: FCT - PTDC/EEA-ACR/67020/2006

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

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

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 (Laboratório Nacional 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.

Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: Mar. 2009
Expected conclusion: Feb. 2012
Classification: AdI – Agencia de Inovação

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Project name: **HELICIM** - Autonomous Helicopter for Critical Infrastructure Monitoring

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

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.

Laboratories: Dynamical Systems and Ocean Robotics Lab
Initiated: Oct. 2007
Expected conclusion: Sep. 2010
Classification: FCT - PTDC/EEA-ACR/72853/2006

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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 leader within ISR: Prof. António Aguiar (ISR/IST)

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.

URL: http://users.isr.ist.utl.pt/~pedro/NAV

Research Areas: Coordinated motion control of autonomous vehicles; Nonlinear control theory; Autonomous marine vehicles; Networked control systems
Laboratories: Dynamical Systems and Ocean Robotics Lab
Project partners: 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)

Initiated: Oct. 2007
Expected conclusion: Sep. 2010
Classification: FCT - PTDC/EEA-ACR/65996/2006

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Project name: **OBSERVFLY** - Uninhabited Aircraft for Marine Science Applications

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

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 harbor (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 proponing 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 behavior 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.

Laboratories: Dynamical Systems and Ocean Robotics Lab
Project partners: IMAR-DOP/University of the Azores (PT), ISR/IST (PT)
Initiated: Nov. 2008
Expected conclusion: Oct. 2011
Classification: FCT - PTDC/MAR/64546/2006

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Project name: **RUMOS** - Robotic Underwater Vehicles and Marine Animals Tracking Systems

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

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

Research Areas: Underwater Positioning Systems, Tracking Systems, Sensor Fusion, Behavior and Ecology of Fishes
Laboratories: Dynamical Systems and Ocean Robotics Lab
Project partners: IMAR/ Department of Oceanography and Fisheries, Univ. Azores
Initiated: 2005
Expected conclusion: 2009
Classification: FCT - POCI/MAR/55609/2004

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: PTDC/EEA-ACR/72201/2006

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Project name: **DELKETI –** Development and Learning of Kernels for Text and Images

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

Project description: Kernel-based methods caused a true revolution in the theory and practice of machine/statistical learning, namely because they allowed adapting classical linear algorithms to the non-linear realm. Recently, kernel methods were further extended to non-vectorial data (strings, trees, graphs, images) with great success. A well known fact is that the performance of kernel-based methods depends heavily on the adequacy of the kernel to the particular problem at hand. This has caused a recent research trend, aiming at approaches which are able to learn "good" kernels directly from training data. This project proposes to contribute to the area of kernel development and learning, with special emphasis on kernels for structured data, such as text or images. More specifically, the proposed project will contribute in the following topics:
1. Universal dissimilarity/distance functions, based on Kolmogorov and Shannon information theories, have been recently proposed. In principle, these dissimilarities will enable defining "universal kernels". We aim at developing techniques to approximate the universal dissimilarity for several types of structured data, such as text and images. This goal will be pursued by using the known ability of compression algorithms (of the Lempel-Ziv type, in the case of text) to approximate the universal distance.
2. "Kernelized" versions of most algorithms for statistical supervised, non-supervised, and semi-supervised learning tasks have been proposed (e.g., support vector machines, kernel Fisher discriminants, kernel principal

component analysis). Accordingly, we will be able to plug the (approximate) universal kernels mentioned above into any kernel-based algorithm, thus extending their applicability to a wide range of structured data types.
3. Kernels implemented via (universal) compression algorithms are necessarily approximations to the theoretical universal kernels. In some cases, these compression-based kernels converge (asymptotically in the sequence length) to the theoretical counterpart, but it is not clearly understood how they behave for finite (small) samples. In this project we will study this problem, aiming to derive concentration bounds for these kernels.
4. An alternative to tailoring kernels to specific problems or using universal-type kernels is to develop algorithms that learn "good" kernels directly from training data. In this project, we will work along this research direction. One of the main goals here, will be to learn optimal combinations of universal kernels for heterogenous data (e.g., classification of web pages, which involve multiple data types: text, links, images).
5. At a final stage of the project, the several kernel-based methods mentioned above will be applied to address problems in text and image analysis. Namely we will target central language processing problems, such as categorization, disambiguation, clustering, and summarization, as well as image analysis tasks, such as image/video classification and content-based image retrieval.

Research Areas: Machine learning
Laboratories: Signal and Image Processing Group
Project partners: Instituto de Telecomunicações, Priberam Informática
Initiated: Jan. 2008
Expected conclusion: Dec. 2010
Classification: PTDC/EEA-TEL/72572/2006

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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: PTDC/EEA-ACR/73749/2006

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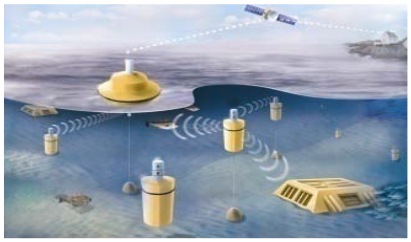
Project name: **UAN** – Underwater Acoustic Network

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

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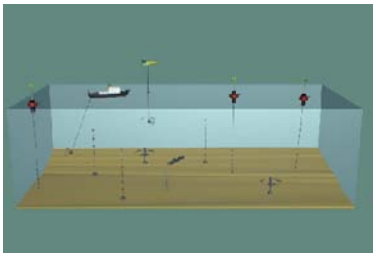
Project name: **PHITOM** - Probabilistic High-Frequency Ocean Tomography for Underwater Communications and Navigation

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: high frequency propagation, underwater communications, bayesian methods.
Laboratories: Signal and Image Processing Group
Project partners: Instituto Superior Técnico (P), CINTAL/UAlg (P).
Initiated: Dec. 2007
Expected conclusion: Nov. 2010
Classification: PTDC/EEA-TEL/71263/2006

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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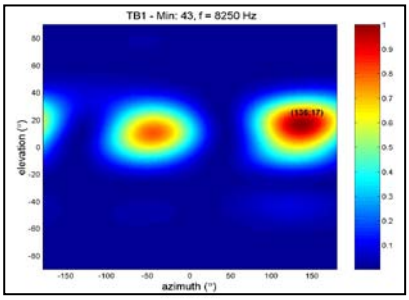
Project name: **SENSOCEAN**

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: PTDC programme

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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
Project partners: CINTAL (UAlg), UTAD, AIBILI (UC), IST
Initiated: Jan. 2008
Expected conclusion: Dec. 2010
Classification: PTDC/EIA/73633/2006

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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

Project partners: AIBILI (UC), FM (UC), Univ. Aveiro, CINTAL (UAlg)
Initiated: Nov. 2007
Expected conclusion: Oct. 2010
Classification: 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 modeling 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 colaborate 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).

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 GPU, 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.

Preliminary results: LAIS application to Aedes aegypti and Dengue epydemic

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.

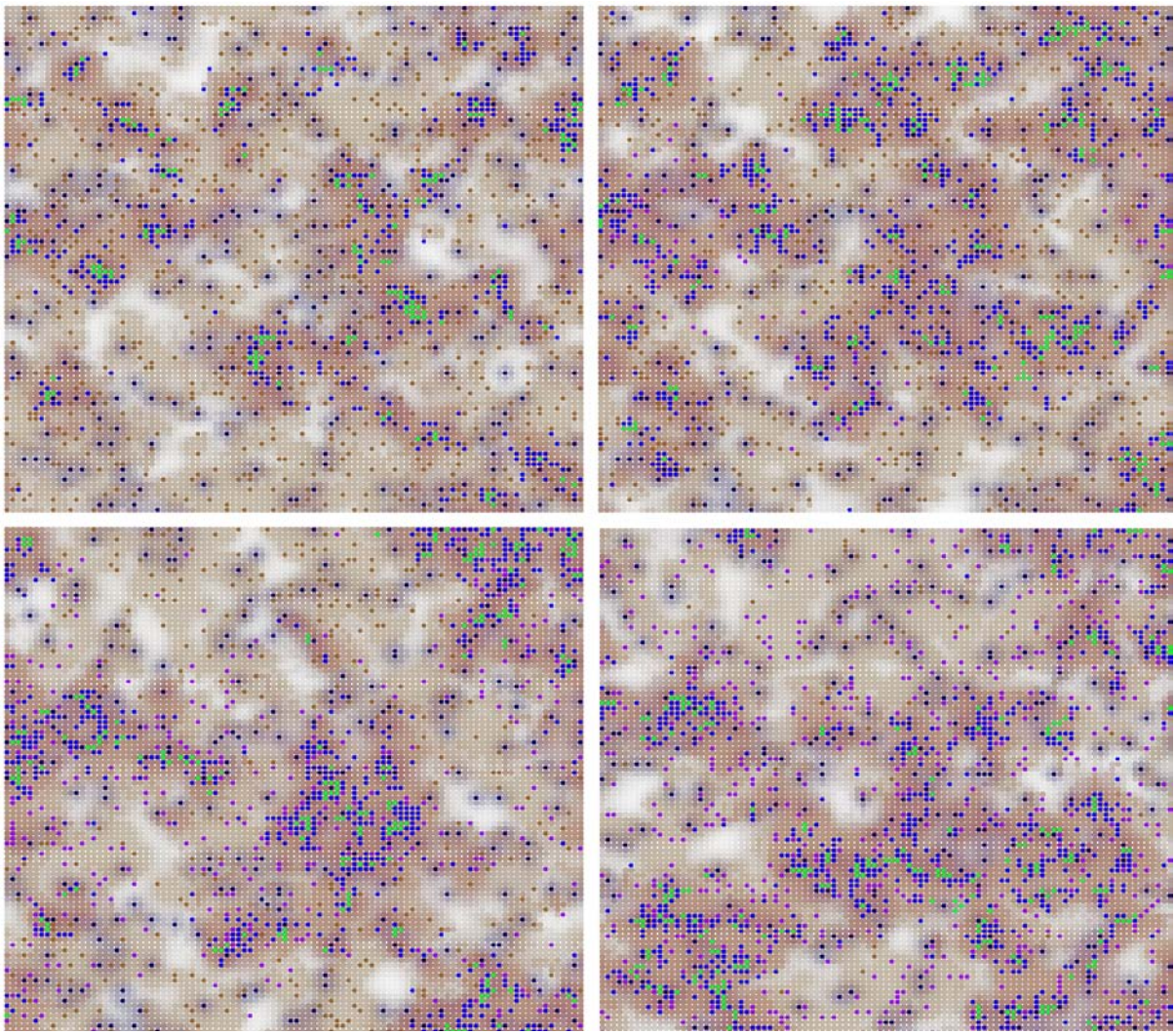

Fig. 1 – The LAIS simulator on Aedes aegypti 4 flashes in time

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.

In figure 1, a new application illustrates the potentials of LAIS, when applied to the simulation spatial and biological behavior of Aedes Aegypti, infected and healthy humans and environment. The simulation model also allowed to test the efficacy of different RIDL release strategies.

Results: Simulation of Antigenic Drif and Shift of Influenza A

Computational models of the immune system and pathogenic agents have several applications, such as the ory testing and validation, or as a complement of first stages of drug trials. One possible application is the prediction of the lethal type of new Influenza A strains, which are constantly reacted due to antigenic drift and shift. Here, we present an agent-based model of immune-influenza A dynamics, with focus on low level molecular anti gen-antibody interactions, in order to study antigenic drift and shift events, and analyze the virulence of emergent strains. At this stage of the investigation, results are presented and discussed from a qualitative point of view again recent and generally recognized immunology and influenza literature.

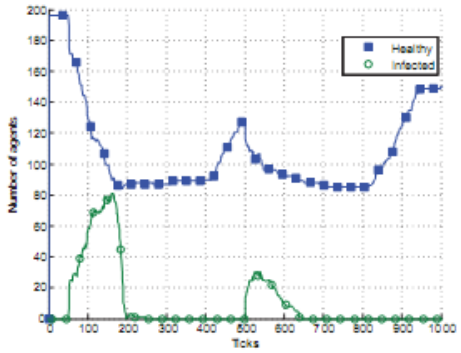

Figure 2: Healthy and infected epithelial cells during challenge from H1N1 subtype.

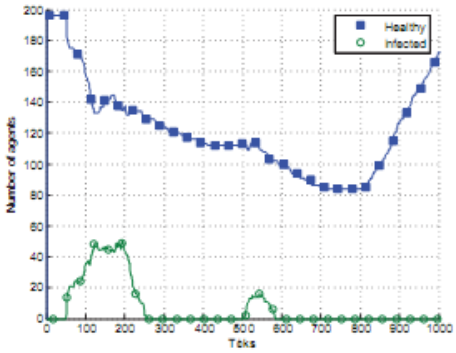

Figure 4: Healthy and infected epithelial cells during challenge from H2N1 subtype.

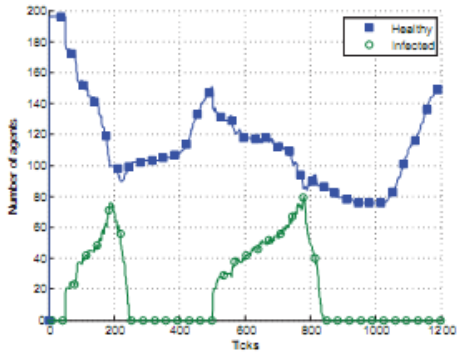

Figure 3: Healthy and infected epithelial cells during challenge from H1N2 subtype.

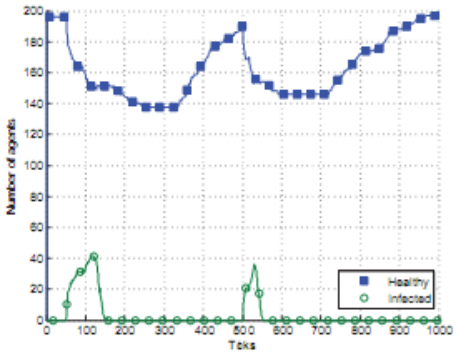

Figure 5: Healthy and infected epithelial cells during challenge from H2N2 subtype.

Fig. 2 – Simulations of Healthy and infected epithelial cells during HaNa challenges

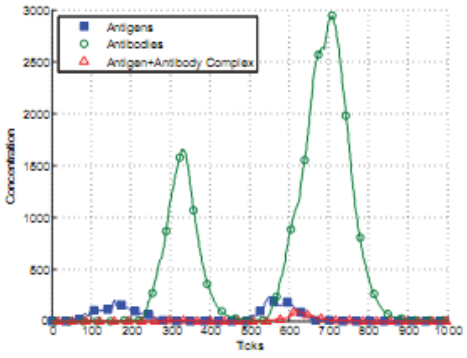

Figure 6: Substance family concentration during challenge from H1N1 subtype.

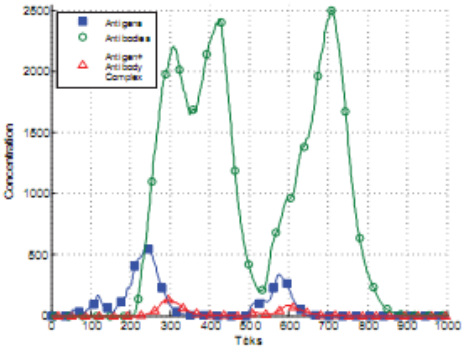

Figure 8: Substance family concentration during challenge from H2N1 subtype.

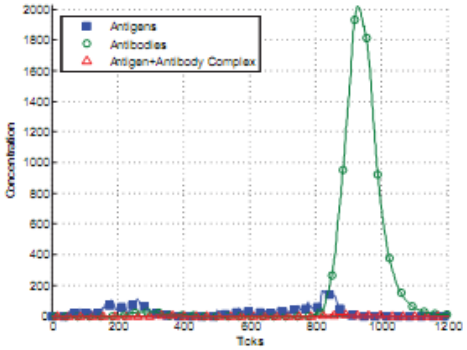

Figure 7: Substance family concentration during challenge from H1N2 subtype.

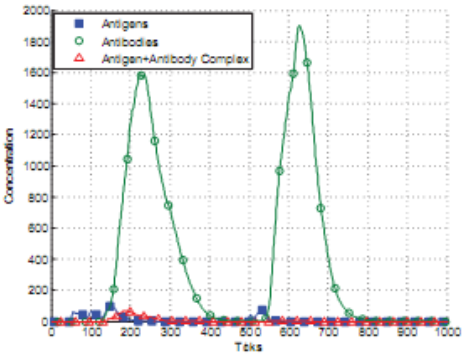

Figure 9: Substance family concentration during challenge from H2N2 subtype.

Fig. 3 – Simulation of substance concentration during HANA challenges

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

2.2 POST-DOCS ACTIVITIES REPORT

2.2.1 Activity Report of Alberto Reyes Ballesteros

Period: 15 January – 15 October 2009
Fellowship: PTDC/EEA-ACR/73266/2006
Project: Decentralized Planning Under Uncertainty for Cooperative Systems (DecPUCS)

Developing intelligent robots or other real-world systems that plan and perform an assigned task is a major goal of Artificial Intelligence and Robotics. In this project we study planning under uncertainty for groups of cooperating multiagent systems. We will develop general methodology and algorithms, and tackle two case studies relevant to society: multi-robot urban search and rescue, and industrial control.

Description of Activities:
1. A manual model construction and implementation of the Russell's grid problem. We first solved the classic Russell's grid problem using Symbolic Perseus. In the original domain, states are locations in a map represented by a set of cells, however we have changed this representation using nodes n1, n2, ...n11 instead of cells. The edges in this new representation denote connectivity paths. The possible noisy actions are discrete orthogonal movements to the right (r), left (l), up (u), down (d), and the null action(). Depending on the agent location, the immediate reward function can assign three possible values:−1/25, +1, −1. The motion planning problem is to automatically obtain an optimal policy for an agent to achieve locations with high utility. This problem was coded and documented in the Perseus's README file to give some directions about the usage of the planning tool.

2. An automatic model construction and implementation of a 3–DOF simulated robot (x,y angle). Different MDP and machine learning algorithms in a well–structured search domain were tested. We used a realistic simulator for a single agent with the capability to add white noise to its action execution mechanism. In this setting, goals are represented as dark-color squares with positive immediate reward (300), and non-desirable regions as light-color squares with negative reward (-300). The remaining regions in the navigation area receive 0 reward (black). Rewarded regions are multivalued and the number of rewarded squares is also variable. The robot sensor system included x-y position, angular orientation, and navigation bounds detection. The possible actions in this experiment were: go forward, clockwise rotation (right turn), counterclockwise rotation (left turn), and the null action. Even when we used a tool for compiling POMDPs, we assumed full observability of states and modeled communication as perfect.

3. A model specification for a multiple-agent system in the USAR domain. We dealed with a problem where a set of robots had to coordinate their actions to do search and rescue tasks during an emergency situation. The test setting was initially inspired in the layout of an IST building. We consider a scenario in which a robot in cooperation with a number of surveillance cameras has to track and reach a person. For simplicity, we assumed we had one robot and one person. The nodes in the map should be viewed as a coarse discretization of the metric space in which both robot and person operate, suitable for the high-level decision making we consider here.

4. Implementation of a 2-channel communication module for the Symbolic Perseus planning system. To make Symbolic Perseus deal with multi–agent systems more naturally and platform–independent, we implemented a socket-based two-channel multi–agent policy server. This new feature enables different agent implementations for quering policies in real time. The 2-channel communication module was implemented in Matlab and Java and it is documented in the Perseus'README file. It allows interfacing Symbolic Persues with any code for policy queries purposes.

5. Formulation of a power plant problem (industrial domain) as a POMDP. We study and stated a problem in an industrial setting where a power plant operator has to make good decisions in order to optimize: i) security in process equipment, ii) risk in plant staff, iii) utility in power generation, and iv maintainance periods. Under this formulation we proposed to solve the problem using a POMDP-based intelligent assistant for plant operators.

Two outcomes of this work are:

A. Reyes and M. T. J. Spaan, "Towards a POMDP-based Intelligent Assistant for Power Plants", POMDP Practioners Workshop ICAPS 2010, Toronto, CA (submitted).

A. Reyes, M. T. J. Spaan and L. Enrique Sucar, "An Intelligent Assistant for Power Plants based on Factored MDPs", ISAP 2009 – 15th International Conference on Intelligent System Applications to Power Systems, Curitiba, Brazil 2009.

2.2.2 Activity Report of Alessandro Saccon

Period: July – December 2009
Fellowship: DENO - PTDC/EEA-ACR/67020/2006

Optimal Control on the Special Euclidean Group SE(3) with Applications to Autonomous Vehicles
The Linear Quadratic Regulator (LQR) problem has received extensive attention from the control community since the 60´s. It is nowadays known as a standard method to obtain asymptotic stabilizing controllers for linear systems. Under suitable conditions on the matrices describing the linear dynamics and the quadratic cost, the optimal control assumes the form of a feedback law which depends on the solution of a matrix differential equation, called the Riccati Differential Equation. The closed loop behavior of the optimal solution can be "shaped" by changing the weighting matrices which define the state and input penalties. The focus of the work done in 2009 was to study different ways of extending the LQR problem to non-compact Lie Groups. In particular, there is an interest in studying systems that evolve on the Special Euclidean group SE(3), which naturally describes the configuration manifold of a vehicle moving in the air or underwater. To this effect, the kernel of an iterative algorithm was developed for the (local) solution of nonlinear optimal control problems on finite dimensional, non-compact Lie groups. This algorithm is based on previous work of Prof. John Hauser, Boulder, CO, USA for the optimization of trajectory functionals on R^n. Roughly speaking, the algorithm is an extension of Newton's method to infinite dimensions. A set of test cases was crated for which explicit solutions are known. These test cases will be used as benchmarks to assess the correctness and verify the second order convergence rate of the proposed algorithm. In the course of the work, Pontryagin's Maximum Principle has been used to derive the necessary conditions for optimality and associated Hamiltonian equations. For a special class of systems and weighting costs defined on the Special Orthogonal group SO(3), it was found that the optimal feedback law can be computed explicitly. It was further proven that the non-differentiable value function obtained is the viscosity solution of an appropriate Hamilton-Jacobi-Bellman equation on SO(3).

References
A. Saccon, J. Hauser and A. Aguiar, "Exploration of Kinematic Optimal Control on the Lie Group SO(3)", submitted to NOLCOS 2010 – 8th IFAC Symposium on Nonlinear Control Systems, Bologna, Italy.

A. Saccon, J. Hauser and A. Aguiar, "Optimal control on non compact Lie Groups: Projection Operator based Optimization", to be submitted to IEEE CDC 2010, Atlanta, Georgia, USA.

2.2.3 Activity Report of Giampiero Salvi

Period: January – June 2009
Fellowship: SFRH/BPD/35050/2007

Description of activities:
The main activity during 2009 was performed within the scope of the CONTACT:

Unsupervised learning of acoustic categories in speech - follow-up Dr. Salvi's Ph.D. work aiming at evaluating machine learning methods for inferring acoustic categories from the regularities that can be observed in speech data.

Learning word/meaning associations - These studies are a continuation of the work done in 2008 and make use of a humanoid robot with the aim of finding associations between the verbal description of manipulation experiments and the "conceptual" descriptions of the same experiments in terms of object properties, actions the robot performs and effects it observes. The assumption is that the associations between words and meanings can be obtained simply by considering co-occurrence, without the use of a grammar. The method involves speech recognition to translate the acoustic input to the robot into words and a probabilistic framework to find co-occurrence between words and meanings. Dr. Salvi co-supervised Verica Krunic during her thesis project on this subject.

Dr. Salvi left the Vislab on June 2009. Since then, the collaboration with the Vislab continued, and a join journal paper on the word/meaning association studies is planned for 2010.

Results of previous work
During 2009, Dr. Salvi co-authored four papers [2,5] based on the results of studies performed during his Ph.D and later when he was back at KTH, Stockholm.

Publications

[1] V. Krunic, G. Salvi, A. Bernardino, L. Montesano and J. Santos-Victor, "Affordance based word-to-meaning association", Proc. of ICRA 2009 - IEEE International Conference on Robotics and Automation, Kobe, Japan, May 2009.

[2] S. Al Moubayed, J. Beskow, A-M Öster, G. Salvi, B. Granström, N. van Son, E. Ormel and T. Herzke, "Studies on Using the SynFace Talking Head for the Hearing Impaired", Proc. of Fonetik 2009, Dept. of Linguistics, Stockholm University, Sweden, June 2009.

[3] S. Al Moubayed, J. Beskow, A-M Öster, G. Salvi, B. Granström, N. van Son and E. Ormel, "Virtual Speech Reading Support for Hard of Hearing in a Domestic Multi-media Setting", Proc. of Interspeech 2009 – 10th Annual Conference of the International Speech Comunication Association, Brighton, Uk, September 2009.

[4] J.Beskow, G. Salvi and S. Al Moubayed, "SynFace - Verbal and Non-verbal Face Animation from Audio", Proc. of AVSP 2009 - International Conference on Auditory-Visual Speech Processing, Norwich, England, September 2009.

[5] G. Salvi, J. Beskow, S. Al Moubayed and B. Granström, "SynFace-Speech-Driven Facial Animation for Virtual Speech-Reading Support", EURASIP Journal on Audio, Speech, and Music Processing, 2009.

2.2.4 Activity Report of Luis Montesano

Period: January – February 2009

Description of activities:
During this year, Luis Montesano has developed his research activities within two different projects currently active at VISLAB: the EU project ROBOTCUB and the FCT project PTDC. Dr. Luis Montesano left Vislab on March 2009. He is still collaborating with members of Vislab.

Luis Montesano joined the ROBOTCUB team within ISR three years ago. In this project, the work have focused mainly on learning models of the interaction of the robot with the environment. In particular we have extended previous work in affordances [1] to consider verbal descriptions of the interactions. The aim is to find associations between the verbal description of manipulation experiments and the "conceptual" descriptions of the same experiments in terms of object properties, actions the robot performs and effects it observes [4].

He also collaborated with some colleagues from the University of Zaragoza. He has continued working in the development of mobile robotics technology for assistive devices. He conducted a pilot study where the developments of the last years (see [2]) have been adapted to a robotic wheelchair for cognitive disabled children. The study has recently been published [9].

Activities within the FCT PCTD project have focused on the development of active learning algorithms for several open problems in robotics related to control and manipulation:

1- First, he developed learning algorithms to learn grasping points from experience based on simple visual features extracted from a single 2D image, kernel regression and Beta-Binomial models. Based on the uncertainty information, several active strategies show how to efficiently explore the space improving random exploration [5,6].

2- Active learning of robot body descriptions, i.e. active calibration of kinematic chains [7]. A Bayesian framework has been developed to estimate the kinematic chain and its uncertainty. Based on this uncertainty, we used recent methods proposed by Dr. Ruben Martinez to actively collect new samples. Results show a considerable decrease on the number of motions required to get a good estimate of the parameters.

3- We have continued previous work on inverse reinforcement learning (IRL) as a way to speed up planning algorithms for complex task. IRL can help in the problems of affordance learning and imitation learning, allowing generalization and knowledge transfer based on the reward function that the agent, the robot, has learned. In that field, we have been working on efficient methods to solve the problem of Bayesian IRL and to apply an active inverse reinforcement learning algorithm to direct exploration towards the most promising areas in the space [7].

[1] L. Montesano, M. Lopes, A. Bernardino and J. Santos-Victor, "Learning Object Affordances: From Sensory Motor Maps to Imitation", IEEE Transactions on Robotics and Automation, 24(1), 2008.
[2] L. Montesano, J. Minguez and L. Montano, "Modelling Dynamic Scenarios for local sensor-based navigation", Autonomous Robots, 2008.
[3] V. Krunic, G. Salvi, A. Bernardino, L. Montesano and J. Santos-Victor, "Associating word descriptions to learned manipulation task models", VisLab-TR 10/2008, IROS-2008 WORKSHOP on Grasp and Task Learning by Imitation, Nice, France, September 2008.
[4] Affordance based word-to-meaning association, ICRA 2009.
[5] Learning grasping affordances from local visual descriptors. Submitted to ICDL 2009.

[6] Active learning for kernel beta regression models, Journal in preparation.
[7] Active Inverse Reinforcement Learning, ECML 2009.
[8] Active Body Schema Learning, ICRA 2010.

"Towards an Intelligent Wheelchair System for Cerebral Palsy Users", Accepted for publication in IEEE Transactions on Neural Systems and Rehabilitation Engineering.

2.2.5 Activity Report of Manuel Lopes

Period: January – September 2009

Description of activities:
Manuel Lopes activities during 2009 were done in different directions: (i) participation in the EU projects ROBOTCUB and HANDLE; (ii) research activities in machine learning and robotics, (iii) education and outreach activities and (iv) management and dissemination.

In the research activities, he actively worked in the development of learning algorithms that allow the robot to discover, through interaction with the environment and other people, how to perform several skills. Low-level skills such as grasping capabilities were learned making use of kernel based Bayesian inference to learn where to grasp objects [f], and using active learning approaches to infer the kinematic structure of rigid bodies [a]. Collaboration with Uppsala University resulted in a computational model for social behaviour in primates [g] and for modelling eye-neck coordination in children [e]. A novel approach for active learning in the context of inverse reinforcement learning was also proposed [c]. Two book chapters were done that incorporate many of previous work [b,h].

Under the education activities he organized, jointly with Luis Montesano the Robot Learning Summer School. Around 70 students and 10 lectures participated in this week long school on the topics of robotics and machine learning. http://vislab.isr.ist.utl.pt/RLSS09/.

Under the management and dissemination activities he worked on the organization of the IEEE Technical Committee on robot learning. Other activities included grant proposals, lab maintenance, and paper review, among others.

[a] R. Cantin-Martinez, M. Lopes and Luis Montesano, "Body Schema Acquisition through Active Learning", ICRA 2010 – IEEE International Conference on Robotics and Automation, Anchorage, Alaska, USA, 2010 (submitted).
[b] M. Lopes, L. Montesano, F. Melo and J. Santos-Victor, "Cognitive Processes in Imitation: Overview and Computational Approaches", in Olivier Sigaud & Jan Peters editors, From motor to interaction learning in robots, Springer Berlin / Heidelberg, pp. 313-355, 2010.
[c] M. Lopes, F. Melo and L. Montesano, "Active Learning for Reward Estimation in Inverse Reinforcement Learning", Proc. of ECML7PKDD 2009 - European Conference on Machine Learning, Bled, Slovenia, September 2009.
[d] D. Figueira, M. Lopes, R. Ventura and J. Ruesch, "From Pixels to Objects: Enabling a spatial model for humanoid social robots", Proc. of ICRA 2009 - IEEE International Conference on Robotics and Automation, Kobe, Japan, May 2009.

[e] M. Lopes, A. Bernardino, J. Santos-Victor, C. von Hofsten and K. Rosander, "Biomimetic Eye-Neck Coordination", Proc. of ICDL 2009 – IEEE International Conference on Development and Learning, Shanghai, China, June 2009.
[f] L. Montesano and M. Lopes, "Learning grasping affordances from local visual descriptors", Pro. of ICDL 2209 - IEEE International Conference on Development and Learning (ICDL), Shanghai, China, June 2009.
[g] M. Lopes, F. Melo, B. Kenward and J. Santos-Victor, "A Computational Model of Social-Learning Mechanisms", Adaptive Behaviour, 467(17), 2009.
[h] L. Montesano, M. Lopes, F. Melo, A. Bernardino and J. Santos-Victor, "A Computational Model of Object Affordances", Advances in Cognitive Systems, 2009.

2.2.6 Activity Report of Naveena Crasta

Period: October – December 2009
Fellowship: DENO- PTDC/EEA-ACR/67020/2006

State Estimation for Systems on SE(3)
State estimation on the special Euclidean group SE(3) is an important problem as it covers a large class of systems. In view of this, we consider the state estimation problem of left-invariant dynamical system evolving on the special Euclidean group SE(3) with implicit output functions. We propose an observer on special Euclidean group SE(3) to estimate the state of the system from the implicit outputs. Under certain conditions we show that the linearized state estimation error converges to zero [N1]. We illustrate the results by considering a robot equipped with a camera measuring the coordinates of a given set of known points and the implementation of the proposed observer.

References
[N1] S. Rodrigues, N. Crasta, A. Aguiar and F. S. Leite, "An exponential observer for systems on SE(3) with implicit outputs", submitted to the book Dynamics, Games and Science in honor of Mauricio Peixoto and David Rand, Springer Verlag Berlin, 2010.

[N2] S. Rodrigues, N. Crasta, A. Aguiar and F. Leite, "State estimation for systems on SE(3) with implicit outputs: An application to visual servoying", submitted to NOLCOS 2010 – 8th IFAC Symposium on Nonlinear Control Systems, Bolonga, Italy.

2.2.7 Activity Report of Plinio Moreno

Period: January – December 2009
Fellowship: URUS

Description of activities:
Plinio Moreno activities during 2009 were done in three different directions: (i) participation in the EU project URUS; (ii) research activities in human activity recognition, (iii) education activities and (iv) management.

In the research activities, he actively worked in the development of classifiers that generate alarm signals for the interaction between humans and a system of distributed sensors, amongst cameras, in an urban environment. The alarm signals relied on: (i) the waving gesture [1] and (ii) the detection of persons and robots in the environment [2]. He was part of the team that designed and implemented both detectors, which

rely on the motion patterns obtained from the optic flow and cope with real-time constraints. The detectors were designed to have good performance on both indoors [3] and outdoors [4] scenarios.

Under the education activities he collaborated in a Ph.D. Thesis, which aims to design learning algorithms suited for the recognition of human actions on videos, which exploit the temporal causality of the low-level features [5].

Under the management activities he worked on grant proposals, lab maintenance, and paper review, amongst others.

[1] P. Moreno, A. Bernardino and J. Santos-Victor, "Waving detection using the local temporal consistency of flow-based features for real-time applications", Proc. of ICIAR 2009 - 6th International Conference on Image Analysis and Recognition, Halifax, Canada, July 2009.
[2] D. Figueira, P. Moreno, A. Bernardino, J. Gaspar and J. Santos-Victor, "Optical flow based detection in mixed human robot environments", Proc. of ISVC 2009 - 5th International Symposium on Visual Computing, Las Vegas, NV, USA, November 2009.
[3] M. Barbosa, A. Bernardino, D. Figueira, J. Gaspar, N. Gonçalves, P. Lima, P. Moreno, A. Pahliani, J. Santos-Victor, M. Spaan and J. Sequeira, "ISROBOTNET: A Testbed for Sensor and Robot Network Systems", Proc. of IROS 2009 – IEEE/RSJ International Conference on Intelligent RObots and Systems, St. Louis, MO, USA, October 2009.
[4] A. Sanfeliu, J. Andrade-Cetto, M. Barbosa, R. Bowden, J. Capitan, A. Corominas, A. Gilbert, J. Illingworth, L. Merino, J. M. Mirats, P. Moreno, A. Ollero, J. Sequeira and M. Spaan, "Decentralized Sensor Fusion for Ubiquitous Networking Robotics in Urban Areas", *Sensors 10(3)*, 2010.
[5] P. Ribeiro, P. Moreno and J. Santos-Victor, "Introducing fuzzy decision stumps in boosting through the notion of neighbourhood", Submitted to Journal of Machine Learning Research, 2009.

2.2.8 Activity Report of Porfírio Silva

Period: January – December 2009
Fellowship: FCT SFRH/BPD/35862/2007

Description of Activities:
The "Institutional Robotics" work program has the overall aim of developing and implementing a new approach to the control of multiple robots' systems, which adds, to the biological inspiration, concepts from social sciences. What follows refers to the second year of work under this programme (conceptual refinement and implementation in simulation). An informal working group has contributed to frame this new approach within the more mature work already taking place at ISLab.

The outcomes of this work during 2009 have been:

Publications

Books chapters

- Artificial Societies and Institutional Environments, Darwin and the Social Sciences , (Proceedings of the International Conference held at Instituto de Ciências Sociais, Lisboa, 3 e 4 de Junho de 2009) (in press).

Journal papers

- Instituição, Porfírio Silva, Pedro Lima, Revista de Comunicação e Linguagens, 40 (Outubro 2009), pp. 97-107, 2009.
- "Intencionalidade: Mecanismo e Interacção", Principia - An International Journal of Epistemology (accepted for publication).
- "O elo perdido das ciências do artificial (ou Da Economia como uma das Ciências do Artificial)", Revista da Faculdade de Letras da Universidade do Porto - Série de Filosofia (accepted for publication).
- "Dar tempo ao tempo. O estudo do comportamento nas ciências do artificial e o problema das escalas temporais", Antropologia Portuguesa (submitted)

Conference papers

- Coordination Through Institutional Roles in Robot Collectives (Extended Abstract), José N. Pereira, A. L. Christensen, Porfírio Silva, Pedro Lima, accepted for presentation, Proc. of AAMAS 2010 - 9th International Conference on Autonomous Agents and Multiagent Systems, Toronto, Canada, 2010.

Talks

- “Vida Institucional Artificial”, Conference Series “From Human Societies to Artificial Societies” (Das Sociedades Humanas às Sociedades Artificiais), 2009 edition), Institute for Systems and Robotics (Instituto Superior Técnico), March 26.
- “Fabulous Races of Humanoid Monsters and Robots”, "Geschichte(n) der Robotik" (Histories of Robots), Jahrestagung der Gesellschaft für Technikgeschichte (The Society for the History of Technology, Germany, Annual Meeting), May 22-24.
- “Institutional Environments and Artificial Societies”, International Conference “Darwin and the Social Sciences”, Instituto de Ciências Sociais da Universidade de Lisboa, June 3-4.
- “Institutional facts: a concept to organize some discussions on comparative social cognition in animals, robots and humans”, Contribution to the session “Interaction with humans in robots and animals”, Discussion Meeting “Comparative Cognition including non-biological species: robots and animals”, CompCog Research Networking Programme funded by the European Science Foundation, Léon, Spain, May 28-29.

In order to improve the effective integration of this approach with the research activities already on development at ISLab:
(a) A PhD student, advised by the scientific responsible for this post-doctoral fellowship, is researching within the framework of institutional Robotics ("societies of robots");
(b) Two “Bolsas de Iniciação à Investigação” (BII) (undergraduate grants) of ISR support: an experiment on some institutional concepts within a virtual world; a deeper understanding of e-puck robots we are already using for Institutional Robotics experiments.

A new case study on institutional robotics concepts has started, both on real robots (eight e-pucks, http://www.e-puck.org/) and in realistic simulation (“realistic” in the sense that the same code is used in simulation and in real robots; see Webots, http://www.cyberbotics.com/). The case study deals with a transportation task and has already some results that are going to be presented at AAMAS 2010 (see above conference papers).

To strengthen the multidisciplinary nature of this work, a set of conferences was launched first in 2008 (from April 7 to July 7) to explore the topic “From Human Societies to Artificial Societies”. The 2009 edition took place from February 26 to March 26 (http://institutionalrobotics2009.isr.ist.utl.pt/).

2.2.9 Activity Report of Rajneesh Sharma

Period: 13 September – December 2009
Project: FCT No. PTDC/EEA-ACR/73266/2006

Description of activities:
The project "Decentralized Planning under Uncertainty for Cooperative Systems" aims at planning under uncertainty for groups of cooperating multi agent systems. We model the sequential decision-making problem as a centralized or decentralized partially observable Markov decision process (POMDP). Decentralized POMDPs (DEC-POMDPs) form a general framework for representing cooperative planning under uncertainty problems.

A major challenge is to scale up DEC-POMDP solution approches or addressing the space and time complexity of DEC-POMDPs. I will attempt to address time complexity by introducing a learning paradigm in the DEC-POMDP framework by casting the problem as a reinforcement learning task. To tackle space complexity I propose to use generic function approximators such as Neural networks, Fuzzy inference Systems.

Optimization of the underlying multi agent POMDP would be cast as a two stage Bayesian game. In the first stage of the proposed line of work, I have done extensive literature survey on the techniques used to solve multi agent POMDPs with particular emphasis on DEC-POMDPs. The idea is to extend Fuzzy Q learning / Fuzzy Markov games to general multi agent POMDPs and constructing the basic framework. In this regard I have already formulated the general architecture of a Bayesian game based DEC POMDP controller.

Initially we propose to test the approach on standard benchmark DEC-POMDP problems such as the DEC Tiger, Broadcast Channel and the Recycling robot. Later on we will implement the proposed methodology on multi robot urban search and rescue problem domain.

Publications in this period:
R. Sharma and M. T. J. Spaan, "A Bayesian Game based Adaptive Fuzzy Controller for Multiagent POMDPs", Proc. of FUZZ 2010 - IEEE International Conference on Fuzzy Systems, 2010 (to appear).

2.2.10 Activity Report of Rita Cunha

Period: January – December 2009
Fellowship: ISR/IST

Description of activities:
Within the scope of my post-doctoral program for 2009, several topics were addressed in the fields of motion control and navigation of autonomous vehicles.

1. Sensor-based nonlinear control and estimation
Sensor-based methods can play an important role in motion control applications for autonomous vehicles, particularly when close interaction with the environment is required. My research activity in 2009 focused on sensor-based control and estimation. This effort resulted in a number of publications on position and attitude estimation based on landmark measurements and vector observations [R1, R8], rigid-body stabilization based on landmark measurements [R3], and attitude estimation using active vision and inertial measurements [R5].
Rigid body stabilization and state estimation are difficult problems that play a central role in many mechanical systems applications. Classical approaches rely on parameterizations of the rotation matrix, such as the Euler

angles or the unit quaternions. These introduce singularities or ambiguities, leading to undesirable solutions. As an alternative approach, we represent rotations matrices in their natural space, as elements of the Special Orthogonal Group SO(3).
In this setting, the solution to the problem of stabilizing a rigid body in position and orientation proposed in [R3] consists of a landmark-based controller for force and torque actuation that guarantees almost global asymptotic stability of the desired equilibrium point. As such the equilibrium point is asymptotically stable and only a nowhere dense set of measure zero lies outside its region of attraction. The controller uses velocity measurements and the position coordinates of a collection of landmarks fixed in the environment. As an additional feature, the control law is designed so as to verify prescribed bounds on the actuation.

In [R1], we address the problem of position and attitude estimation, based on landmark readings and velocity measurements. A derivation of a nonlinear observer on SE(3) is presented, using a Lyapunov function conveniently expressed as a function of the difference between the estimated and the measured landmark coordinates. The resulting feedback laws are explicit functions of the landmark measurements and velocity readings, exploiting the sensor information directly in the observer. The proposed observer yields almost global asymptotic stabilization of the position and attitude errors and exponential convergence in any closed ball inside the region of attraction. Also, it is shown that the asymptotic convergence of the estimation error trajectories is shaped by the landmark geometry and observer design parameters.

The problem of non-ideal velocity readings is also considered in [R1] and [R8], and the observers are augmented to compensate for bias in the velocity measurements. In [R1] the position, attitude, and bias estimation errors are shown to converge exponentially fast to the desired equilibrium points, for bounded initial estimation errors, whereas in [R8] almost global asymptotic stability of the origin of the attitude error system is obtained and exponential convergence is guaranteed for an explicit region in the state space. In addition, stability of the observer in the presence of angular measurement noise is obtained, and convergence to a desired neighborhood of the origin, for any initial condition in a known region, can be guaranteed by properly defining the observer parameters.

In [R5], the observer structures proposed in [R1, R8] are explored and combined with vision-based techniques to address the problem of estimating the attitude of a rigid body equipped with a triad of rate gyros and a pan and tilt camera. The nonlinear attitude observer integrates angular velocity measurements from rate gyros, with images of a planar scene provided by the camera. By exploiting directly sensor information, i) a stabilizing feedback law is introduced and exponential convergence to the origin of the estimation errors is shown; ii) an active vision system is proposed that relies on an image-based exponentially input-to-state stable (ISS) control law for the camera pan and tilt angular rates to keep the features in the image plane. The discrete time implementation of the observer makes use of recent results in geometric numeric integration to preserve the rotation matrix properties.

2. Trajectory tracking and path following control of autonomous vehicles

My research activities in 2009 were also devoted to the topics of trajectory tracking and path following control of autonomous vehicles. Different methodologies and different vehicles were considered, including multi-rate techniques for trajectory tracking control of rotorcraft [R2], preview control methods for bottom-following using underwater vehicles [R4], nonlinear backstepping techniques for trajectory tracking and path following control of quadrotors [R6, R7], model predictive control methodologies for trajectory tracking control of autonomous surface craft [R9], and L1 adaptive control applied to autonomous rotorcraft [R10].

The multi-rate methodology proposed in [R2] provides a natural way to address the integrated guidance and control problem for autonomous vehicles when the outputs are sampled at different instants of time. The

controller structure proposed solves the regulation problem for non-square multi-rate systems with more measured outputs than inputs. Based on this structure, an implementation for a gain-scheduled controller is obtained that satisfies an important property known as the linearization property. The method is applied to the problem of steering an autonomous rotorcraft along a predefined trajectory defined in terms of space and time coordinates.

In [R4], we address the problem of bottom-following for autonomous underwater vehicles (AUVs) and present a solution that relies on the evaluation of the terrain characteristics ahead of the vehicle using echo sounders. The methodology used poses the problem as a discrete time path following control problem where a conveniently defined error state space model of the plant is augmented with bathymetric (i.e., depth) preview data. A piecewise affine parameter-dependent model representation is adopted that describes the AUV linearized error dynamics for a predefined set of operating regions. For each region, a state feedback control problem for affine parameter-dependent systems is posed and solved using linear matrix inequalities (LMIs). The resulting nonlinear controller is implemented as a gain-scheduled controller using the D-methodology.

Nonlinear backstepping techniques rooted in Lyapunov stability theory are explored in [R6] and [R7] to address the problems of trajectory tracking and path following control of quadrotors. In [R6], the trajectory tracking problem is formulated so as to take into account force disturbances acting on the vehicle and enforce bounds on the actuation. The proposed solution consists of a nonlinear adaptive state feedback controller for thrust and torque actuation that i) guarantees asymptotic stability of the closed-loop system in the presence of constant force disturbances and ii) ensures that the actuation does not grow unbounded as a function of the position errors. The path following solution proposed in [R7] combines a nonlinear state feedback controller for thrust and torque actuations with a path following timing law that i) guarantees global asymptotic convergence of the path following error to zero, for a large class of three-dimensional paths, ii) ensures that the actuation does not grow unbounded as function of the position errors, and iii) allows for zero thrust actuation to be applied when the vehicle is converging to the path.

The work reported in [R9] addresses the problem of trajectory tracking control of autonomous surface craft (ASC) in the presence of constant ocean currents. The solution proposed is rooted in nonlinear model predictive control (MPC) techniques and addresses explicitly state and input constraints. Whereas state saturation constraints are added to the underlying optimization cost functional as penalties, input saturation constraints are made intrinsic to the nonlinear model used in the optimization problem, therefore reducing the computational burden of the resulting MPC algorithm.

The L1 adaptive control theory is used in [R10] to design a high bandwidth inner loop controller that provides attitude and velocity stabilization of an autonomous small-scale rotorcraft in the presence of wind disturbances. The nonlinear model of the vehicle is expressed as a linear time-varying system for a predefined region of operation, for which an L1 adaptive controller is designed. The L1 adaptive controller ensures that an uncertain linear time-varying system has uniformly bounded transient response for system's input and output signals, in addition to stable tracking. The performance bounds of L1 adaptive controller can be systematically improved by increasing the adaptation rate without hurting the robustness of the system.

Journal Publications

[R1] J. Vasconcelos, R. Cunha, C. Silvestre, and P. Oliveira, "A nonlinear position and attitude observer on SE(3) using landmark measurements", Systems and Control Letters, in press, 2009.

[R2] D. Antunes, C. Silvestre, and R. Cunha, "On the design of multi-rate tracking controllers: Application to rotorcraft guidance and control", International Journal of Robust and Nonlinear Control, in press, 2009.

[R3] D. Cabecinhas, R. Cunha, and C. Silvestre, “Almost global stabilization of fully-actuated rigid bodies”, Systems and Control Letters, 58(9):639-645, 2009.
[R4] C. Silvestre, R. Cunha, N. Paulino, and A. Pascoal, “A Bottom-Following Preview Controller for Autonomous Underwater Vehicles,” IEEE Transactions on Control Systems Technology, 17(2):257-266, 2009.

Conference Publications

[R5] S. Brás, R. Cunha, J. Vasconcelos, C. Silvestre, and P. Oliveira, “Nonlinear Attitude Estimation Using Active Vision and Inertial Measurements”, Proc. of CDC 2009 - IEEE Conference on Decision and Control, December 2009.
[R6] D. Cabecinhas, R. Cunha, and C. Silvestre, “Rotorcraft path following control for extended flight envelope coverage”, Proc. of CDC 2009 - IEEE Conference on Decision and Control, December 2009.
[R7] R. Cunha, D. Cabecinhas, and C. Silvestre, “Nonlinear Trajectory Tracking Control of a Quadrotor Vehicle”, Proc. of ECC 2009 - European Control Conference, August 2009.
[R8] J. Vasconcelos, R. Cunha, C. Silvestre, and P. Oliveira, “Stability of a Nonlinear Attitude Observer on SO(3) with Nonideal Angular Velocity Measurements”, Proc. of ECC 2009 - European Control Conference, August 2009.
[R9] B. Guerreiro, C. Silvestre, R. Cunha, and A. Pascoal, “Trajectory Tracking Nonlinear Model Predictive Control for Autonomous Surface Craft”, Proc. Of ECC 2009 - European Control Conference, August 2009.
[R10] B. Guerreiro, C. Silvestre, R. Cunha, C. Cao and N. Hovakimyan, “L1 Adaptive Control for Autonomous Rotorcraft,” Proc. Of ACC 2009 - IEEE American Control Conference, June 2009.

2.2.11 Activity Report of Ruben Martinez-Cantin

Period: January – December 2009
Fellowship: FCT SFRH/BPD/48857/2008

During this year we have tackled the problem of body schema learning and developed an algorithm for learning the parameters of the body schema model recursively, being able to adapt the model following changes in the schema, such us grasping a tool or a joint failure. For that purpose, we use a modified version of the Recursive Least Squares (RLS), which has proven to be more efficient and accurate than the state-of-the-art algorithms for body schema estimation. This method also allows us to update the knowledge of the body sequentially as new data arrived, allowing for dynamic schemas, such us incorporating a new tool or re-planning after a joint failure.

Furthermore, we have developed a general framework for active learning and experimental design in robotics. The main idea is that the robot is a physical agent, which is able to explore and sense the environment autonomously. Therefore, we can exploit that capability by selecting the observations and interactions that we want for the robot to perform during the learning process. Instead of providing the robot with a large dataset, we let the robot interact with the environment and decide based on the information obtained so far. Sometimes, that interaction is done using simulations based on the internal models that the robot has obtained up to that point, allowing to predict the result while saving energy and avoiding dangerous trajectories or manipulations.

Based on that framework, we extended the work on body schema learning, allowing the robot to decide where to move the arm in order to obtain new data. That requires the robot to simulate some “cleverly” selected outcomes and find the most informative. We found that our setup resembles the problem of derivative-free global optimization of expensive functions. For that purpose, we have developed and tested two different algorithms (EGO and DIRECT). The first algorithm, has been published in the proceedings of the Workshop on Robotics and Regression at the Robotics: Science and Systems conference. Our implementation of EGO includes

some improvements that reduce the computational cost from O(n3) to O(n2) using some linear algebra tricks to update the inverse of a matrix. [1]

The second algorithm outperforms in time and results our first approach and has been submitted to the ICRA, [2]. This framework, has been applied in other fields as Simultaneous Localization and Mapping (SLAM). In that problem, a mobile robot has to build a map of the environment, which is unknown beforehand, based on on-board sensor. At the same time, it has to localize itself in that map in order to navigate and solve tasks efficiently. The point of active SLAM is to explore the terrain autonomously, improving the knowledge of the map and the accuracy in localization, while doing some navigation tasks. The system has to be able to plan ahead in an uncertain environment, considering the current and posterior belief.

This problem results in a tremendous computational burden, especially considering that the robot state, the map parameters and the actions are represented in continuous spaces and related using nonlinear functions. For that reason, active learning, which automatically reduce the number of evaluations, is of paramount importance. This application resulted in a journal paper appeared in Autonomous Robots - Special Issue on Robot Learning [3].

We are currently working on an autonomous calibration system for fish-eye cameras mounted on mobile robots. The theoretical background resembles the work commented beforehand, adding the complexity of the projective model of the camera. Furthermore, we are also working on sensor network calibration using a mobile agent.
Again, both problems will be solve using our active learning framework.

We have continued previous work on inverse reinforcement learning (IRL) as a way to speed up planning algorithms for complex task. IRL can help in the problems of affordance learning and imitation learning, allowing generalization and knowledge transfer based on the reward function that the agent, the robot, has learned. In that field, we have been working on efficient methods to solve the problem of Bayesian IRL and to apply an active inverse reinforcement learning algorithm to direct exploration towards the most promising areas in the space.

Finally, we organize a workshop on Adaptive Sensing, Active Learning and Experimental Design: Theory, Methods and Applicationsat the Neural Information Processing Systems (NIPS) 2009. The workshop is co-organized with Prof. Rui Castro from Columbia Univ and Prof. Nando de Freitas from UBC and will have several invited speakers [4].

References:
[1] http://users.isr.ist.utl.pt/~rmcantin/papers/workshop.pdf
[2] http://users.isr.ist.utl.pt/~rmcantin/papers/10ICRA_abs.pdf
[3] http://users.isr.ist.utl.pt/~rmcantin/papers/MartinezCantin09AR.pdf
[4] http://users.isr.ist.utl.pt/~rmcantin/nips2009.php

2.3 THESES

In this section the Doctoral and Master theses concluded, or in progress, during 2009 at ISR-Lisbon are identified.

2.3.1 Theses Concluded during 2009

DOCTORAL THESES (4)

António João Silva, "Environmental-based Underwater Communications", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, March 2010.

Abstract: The present thesis aims at the development of an environmental-based equalizer for shallow water coherent communications. In recent years time-reversal aroused as a viable option for underwater communications since its focusing property allows for a significant signal to noise ratio enhancement and inter symbolic interference reduction. In order to use time reversal in an operational modem the main drawbacks were identified as the performance loss due to the source-vertical-line-array geometric mismatch (i.e. source-array relative range and depth variations) during the data transmission and the optimization concerning the multipath spread of underwater channel impulse responses in a noisy environment. For the time-reversal environmental geometric mismatch compensation a physical model based on waveguide invariants of the acoustic channel was developed. It makes use of the frequency/range invariant and of the frequency/depth invariant. With such a physicalmodel in hand an environmental-based equalizer was developed. The multipath spread that guarantees the maximum of the signal to noise ratio is given by the time-reversal overall impulse response maximum power that can be computed using channel impulse response estimates. Such optimum signal to noise ratio results in a suboptimum inter-symbolic interference compensation with, however, values close to the optimum. In parallel with the scientific objectives, the development of a surface buoy prototype – the Acoustic Oceanographic Buoy (AOB) – was carried out. The AOB is an advanced sonobuoy with a long and dense acoustic/oceanographic vertical-line-array and with additional processing capabilities. The AOB was tested in six sea trials where its telemetry capabilities where successfully proven, and was used to acquire the real data used to test the developed environmental-based equalizer. The time-reversal optimization concerning the multipath spread was validated with real data at 400 and 2000 bits per second, as well as the time-reversal environmental-base equalizer that showed a mean squared error gain up to 5.5 dB over the non equalized time-reversal data.

Keywords: Underwater acoustic communication, matched field processing, time-reversal, waveguide invariants, environmental-based equalizer.

Members of the thesis committee:
Presidente do Júri: Reitor da Universidade Técnica de Lisboa
Sérgio Manuel Machado Jesus, Prof. Associado, UALG, supervisor
Victor Alberto Neves Barroso, Prof. Associado, IST
Christoph Friedrich Mecklenbrauker, Prof., INTHFT - Universidade Técnica de Viena
José Manuel Bioucas Dias, Prof. Associado, IST
João Pedro Castilho Pereira Santos Gomes, Prof. Auxiliar, IST
James Calvin Preisig, Associate Scientist, Woods Hole Oceanographic Institute

Sónia Marques, "Decentralized Low Communication 6DoF Full State Formation Navigation", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

Abstract: Formation Flying Spacecraft have become the key enabling technology for today and future space missions. This concept has enabled scientific objectives to move beyond those accomplished by the restricted single monolithic structures predominant until now. However, design and implementation of this type of multi-spacecraft systems is not simply scalable from that of single spacecraft platforms, as extra factors such as coordination within the formation need to be considered.

This work was motivated by the need to develop a method that uses a decentralized architecture to estimate the 6 Degrees of Freedom (DoF) translational and rotational components of a full-order state vector of a formation of N-spacecraft. This would have the advantage of eliminating the dependence on a single master spacecraft while still enabling the full state to be determined.

The thesis presents a general formulation of the problem of estimating the full state of N-vehicle formation. Graph theory was applied with three main objectives in mind: to model the measurements and the information flow within the formation; to analyse the impact of a connection breakdown (a vehicle failure, for example) on the performance of the navigation algorithm; and to establish requirements for the algorithm to be robust to changes in the topology of the measurement graph and the information flow graph. The estimation method is based on an Extended Kalman Filter (EKF) for measurements obtained locally by each vehicle's sensor and a Covariance Intersection (CI) algorithm for information communicated by other vehicles in the formation.

The developed algorithms are applied to the realistic simulation of a three-spacecraft system that emulates the European Space Agency (ESA) Darwin mission. Results of experiments with and without the estimator in the Guidance and Control loop are presented. Realistic simulations show that the implementation of the proposed 6DoF navigation filter was successful. The use of information from other vehicles estimates to compute the non-observable state vector components not estimated locally was shown to be both important and feasible, as was the use of the CI method to fuse correlated entities. Other relevant results include the accuracy of the achieved full state vector estimates and the navigation quality by comparison with the PCRLB (Posterior Cramer-Rao Lower Bound); the capability of the navigation algorithms to overcome the initial error, to overcome environmental disturbances and to track control changes; the navigation's robustness to uncertainty of the parameters; and the importance of tuning the process and measurement noise covariance matrices using the Normalized Estimation Error Squared (NEES) and the Normalized Innovation Squared (NIS) consistency tests, as confirmed by the comparision with the PCRLB.

Keywords: Decentralized navigation, formation state estimation, extended Kalman filter, covariance intersection, algebraic graph theory, formation flying spacecraft.

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Valdinei Silva, "Extracção de Preferências por meio de Avaliações de Comportamentos Observados", Ph.D. Thesis, co-tutela, U. São Paulo, Brazil and Instituto Superior Técnico, Lisbon, Portugal, 2009.

Abstract: Recently, computer systems have been delegated to accomplish a variety of tasks, when the computer system can be more reliable or when the task is not suitable or not recommended for a human being. The use of preference elicitation in computational systems helps to improve such delegation, enabling lay people to program easily a computer system with their own preference. The preference of a person is elicited through his answers to specific questions, that the computer system formulates by itself. The person acts as an user of the computer system, whereas the computer system can be seen as an agent that acts in place of the person. The structure and context of the questions have been pointed as sources of variance regarding the user's answers, and such variance can jeopardize the feasibility of preference elicitation. An attempt to avoid such variance is asking an user to choose between two behaviours that were observed by himself. Evaluating relatively observed behaviours turn questions more transparent and simpler for the user, decreasing the variance effect, but it might not be easier interpreting such evaluations. If divergences between agent's and user's perceptions occur, the agent may not be able to learn the user's preference. Evaluations are generated regarding user's perception, but all an agent can do is to relate such evaluation to his own perception.
Another issue is that questions, which are exposed to the user through behaviours, are now constrained by the environment dynamics and a behaviour cannot be chosen arbitrarily, but the behaviour must be feasible and a policy must be executed in order to achieve a behaviour. Whereas the first issue influences the inference regarding user's evaluation, the second problem influences how fast and accurate the learning process can be made. This thesis proposes the problem of Preference Elicitation under Evaluations over Observed Behaviours using the Markov Decision Process framework and theoretic properties in such framework are developed in order to turn such problem computationally feasible. The problem o different perceptions is analysed and constraint solutions are developed. The problem of demonstrating a behaviour is considered under the formulation of question based on stationary policies and non-stationary policies. Both type of questions was implemented and tested to solve the preference elicitation in a scenario with constraint conditions.

Keywords: Preference elicitation, expected utility theory.

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Carlos Miguel da Costa Fernandes, "Diversity-Enhanced Evolutionary Algorithms for Dynamic Optimization", Ph.D. Thesis, Instituto Superior Técnico, Lisboa, Portugal, December 2009.

Abstract: Many industrial applications have dynamic components that lead to variations of the fitness function and Genetic Algorithms (GAs) amativeness is an appropriate tool to solve this type of problems. The thesis proposes two new evolutionary methods to tackle dynamic problems. The first acts upon mating and avoids crossover between similar individuals, via a self-regulated mechanism, thus preserving genetic diversity. The second is a new mutation operator able to evolve self-regulated mutation rates with a particular distribution that is suited for dynamic optimization. Finally, a very efficient hybrid method that combines both strategies is proposed. The objective and main claim is the possibility of designing nature-inspired protocols for GAs that

are efficient when evolving on dynamic environments while preserving algorithms' complexity and not requiring a priori information about the problem.
The proposals were tested on a wide range of problems and were able to outperform frequently other GAs, namely when the changes are not very fast. The hybrid scheme proved to be particularly effective since it broadened the range of dynamics in which each method by itself excels. As projected, the proposed techniques are robust and do not increase parameters' space, thus fulfilling necessary conditions for real-world applications.

Members of the Thesis Committee:
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MASTER THESES (32)

Henrique de Castro Martins, "Augmented Reality for the Teleoperation of Robot RAPOSA", MSc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2009.

Abstract: This thesis proposes an alternative approach to the existing teleoperation methods most often found in search and rescue (SAR) robotics. These methods involve using a graphical user interface (GUI) on the remote console, through which the operator visualizes the robot's environment in two small scaled side–by–side 2D images and a common gamepad to control the robot locomotion.
The introduction of a Head Mounted Display (HMD) allows the possibility of perceiving the robot world in three dimensions (3D) and in larger scale. More- over, the rotational misalignment of the robot's frontal cameras is corrected using an image rectification algorithm. In addition, the HMD is equipped with an inte-grated head tracker, which permits controlling part of the robot motion through head motion, thus providing a more intuitive and less error prone control over the robot.
The evaluation of the proposed system involved the execution of several experiments by a group of users. The obtained results suggest that the innovative visualization/control method proposed in this work may yield significant benefits to the effectiveness of the SAR operation. In particular, the user's depth perception improved significantly when using the HMD, as well as their situa- tional awareness. Furthermore, the user's performance during a simulated SAR operation was also enhanced, both in terms of operation time and successful identification of objects of interest.

Keywords: Search and Rescue Robotics, Head–Mounted Display, Stereopsis, Teleoperation, Image Rectification.

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Jorge Miguel de Freitas Ferraz, "Increasing Autonomy For The Robot RAPOSA", MSc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2009.

Abstract: During recent years researchers have been making an effort to increase the autonomy level of search and rescue (SAR) mobile robots. One interesting problem that these robots face is the process of climbing stairs autonomously. In disaster scenarios, stairs are the most common way of maneuvering throughout a multi-level building. RAPOSA is a SAR robot originally designed to be teleoperated, al- though has been subject of autonomy upgrades. In this thesis, an algorithm for the autonomous stairs climbing is presented. The solution has a simple approach, contributing to a robust behavior.

The method proposed uses mainly the robot Euler angles, as measured by an accelerometer sensor, after a sensor calibration. Pitch and roll are obtained directly from the accelerometer, instead yaw is subject of an estimation. This estimation contributes also to a better awareness by human operators. In case of existing objects obstructing the way, a path to avoid it is followed, by suggestion of the operator.

A skilled operator is required to climb stairs manually, therefore, doing so autonomously allows for a more efficient robot operation in SAR scenarios. Results have shown that the proposed algorithm was capable of climbing several kinds of stairs. An empirical evaluation comparing the proposed control algorithm with human teleoperation was also conducted, showing an overall more reliable and faster operation in majority of the tests. This difference is even more significant when the operator is limited to the camera view of the robot, which is the most common situation on the field.

Keywords: Search and Rescue Robots, Autonomous Climbing Stairs, Motion Control.

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André Ribeiro, "Seguimento de jogadores num jogo de futebol", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2009.

Abstract: The analysis of human movement has been widely studied and has received special attention of researchers in the areas of image processing and vision. The fact that there is a wide spectrum of situations, such as tracking human figures in film sequences or determining the activity that is being held by the human (walk, run), makes the investment in research viable.

In this thesis, we focus on the problem of the detection and the tracking of football players without considering the large variations in their silhouettes. It is quite a challenging task due to many difficulties such as player occlusion, similar player appearance, video blur and the emergence of evidences from external environment.

We propose a solution for player tracking which is based on a multiple object tracker, a particle filter named Condensation where each player is independently fitted to a model, and the sampling probability for the group of samples is calculated as a function of the fitness score of each player.

This solution is widely used in sports in which the relative position of the player within the team has to be determined as a time function. If this data is sufficiently accurate, a range of additional information can be determined, such as player's speed and distance accomplished.

Keywords: Automatic Sample Detection, Particle Filter, Condensation, Multi-Part Model, Occlusion

Members of the Thesis Committee:
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Ricardo S. Cabral, "Joint Estimation of Correspondence and Motion using Global Rigidity and Local Descriptors", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, July 2009.

Abstract: In this thesis we present a new approach to the modeling of the correspondence problem for rigid and Lambertian objects within a Structure from Motion framework. Our goal is to solve for correspondences and camera motion altogether, using only a pair of images with no additional information.
The approach presented takes as input sets of point coordinates, specifically a set of points in the first image, each with a set of correspondence candidates in the second image presenting the same intensity value. With this data, we estimate motion between both cameras and select a number of most likely candidates for each point in the first image (which, in particular, can be the case of 1-to-1 correspondence). To fulfill this goal, our work merges information from brightness cues available in image points extracted using local descriptor algorithms with a model that constrains point trajectories due to the rigidity of the object.
The use of both these constraints allows us to formulate the estimation of correspondences, motion and depth within a single optimization problem. We describe the set of possible motions as a Stiefel manifold, whose properties allow us to solve the optimization problem by minimizing a cost function over a two-parameter search grid The resulting algorithm — Correspondence Estimation using Rigidity and local Descriptors, or CERD — has polynomial complexity, therefore bypassing the combinatorial explosion typically associated with the correspondence problem, and has optimal properties when the camera parameters are known.
Our experiments with synthetic and real data show that CERD is able to accurately estimate correspondence and motion, being able to cope with a large number of outliers and light occlusion. Additionally, it's ability to be coupled with any feature extraction algorithm (e.g., SIFT) allows for extra versatility and broadens it's applicability to a wide range of scenarios.

Keywords: Stereo Vision, Image Matching, Correspondence problem, Permutations, Structure from Motion, Computer Vision, Depth Perception, Pixel brightness, Pixel intensity, Rigid object, Lambertian object.

Members of the Thesis Committee:
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Sérgio Pequito, "The Entropy Penalized Minimum Energy Estimator", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, July 2009.

Abstract: The determination in real time of an estimative of the state of a given nonlinear system from partial and noisy measurements of the inputs and outputs and inexact knowledge of the initial condition has been a fundamental and a challenging problem in theory and applications of control systems. By far, the extended Kalman filter (EKF) is the most widely used method for estimating the state. It is obtained by linearizing the nonlinear dynamics and the observation along the trajectory of the estimate. However, since it is only a local method, it often fails to converge.

Particular interesting classes of optimal nonlinear observers are the minimum energy estimator (MEE) and the closely related H-infinity estimator. The MEE was first proposed by Mortersen and further improved by O. Hijab. The main strategy is to compute an estimate of the state that is compatible with the system's dynamics and measured outputs and minimizes the energy of the noise and disturbances. One important feature of this approach is if the system is linear, than one would obtain precisely the Kalman-Bucy filter.
However, in general, both minimum-energy and H-infinity state estimators for nonlinear systems lead to infinite-dimensional observers whose state evolves according to a first-order nonlinear PDE of Hamilton-Jacobi (HJ) type, driven by the observations.
This thesis addresses the state estimation problem of nonlinear systems using a MEE approach and proposes an entropy penalized scheme to approximate the viscosity solution of the resulting HJ equation.
The main contributions of the thesis are threefold:
i) an explicit observer algorithm, called entropy penalized minimum energy estimator, that is iterative and filtering-like is derived,
ii) a proof of convergence of the algorithm is presented, and
iii) for first and second order approximations of the state equation, a computationally efficient procedure to estimate the state is derived.
Simulation results obtained with nonlinear examples with the feature that the EKF do not converge to the correct value illustrate the performance of the proposed algorithm.

Keywords: Nonlinear Observers, H - infinity Observer, Viscosity Solutions, Entropy Penalized Method, Minimum Energy Estimator

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André Ramalho dos Santos Rosado, "Detecção Automática de Actividade Epileptiforme Interictal no EEG", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, September 2009.

Abstract: The diagnosis of epilepsy generally includes visual inspection of EEG recorded data by the Neurologist, in order to check for the presence of transient waveforms, the interictal epileptiform discharges. As this process is generally time-consuming, particularly in the case of ambulatory long-term EEG records, there is a need for an automatic detection system that guarantees a high level of performance.This project aimed to develop an automatic detector of epileptiform discharges, which can process the complete signals and apply decision criteria to achieve a common high value for Sensibility and Specificity. The detection algorithm is defined by a multi-stage approach, using EEG analysis techniques as Wavelet Transform and Mimetic Analysis, complemented with a classification based on Fuzzy Logic. In order to perform the performance tests, data from several epileptic patients was collected with epileptiform activity marked by a Neurologist. In these records, the average values obtained for Sensibility and Specificity were respectively higher than 80% and 70%.

Keywords: Electroencephalogram, Interictal Discharges; Wavelet Transform; Mimetic Analysis, Fuzzy Logic.

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Patrícia Figueiredo

João Pedro de Matos Rodrigues, "Monitoring Electrocortical Activity During EEG Biofeedback", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2009.

Abstract: The purpose of this work was to develop an EEG biofeedback platform. Additionally, it was studied how voluntary training of specific electro cortical activity, using the EEG biofeedback platform, produces any changes in the electroencephalogram along with the electroencephalographic correlates of memory. The human brain was seen as an electrochemical machine capable of receiving stimuli and adapt accordingly. Relevant EEG activity was fed back to the trainee by a Brain Computer Interface in an intelligible way allowing the identification of phasic changes in the EEG and what cognitive state caused it, facilitating self-regulation. The results from this study showed that it is possible to learn changing some rhythmical activity in the EEG after a few feedback sessions, in this case, the amplitude of the alpha activity. A positive relation between this frequency band and cognitive processes was also observed.

Keywords: EEG Biofeedback, Neurofeedback, Brain-Computer Interfaces, Signal Processing.

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Dulce Isabel Viegas Calçada, "Modeling of the Phisiology of *D. Hansenii* usin Population-based Search Methods for Parameter Estimation", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2009.

Abstract: This work tackled the problem of finding a mathematical model capable of describing the physiology of the yeast *Debaryomyces hansenii* (*D. hansenii*), under certain conditions. Nine alternative physiological models were developed and formulated as nonlinear systems of ordinary differential equations, describing the temporal rate of change of the concentrations of eight substances of interest, as a function of a number of parameters (26 to 31, depending on the model).

The estimation of the parameters of these models was accomplished by fitting them to experimental data consisting of time courses for the concentrations of the aforementioned substances. The resulting optimization problem aimed at minimizing, with certain constraints, an objective function (OF) consisting of the sum of squared differences between the models' predictions and the experimental data. Given the limited success of classical deterministic methods in solving this complex problem, two population-based stochastic algorithms were proposed to solve it: a genetic algorithm (GA) and particle swarm optimization (PSO). The performance of these two algorithms was tested on one model and one data group, using different settings for their operating parameters. It was found that the PSO, with settings i) resulting in a convergent behavior, with oscillation or zigzagging, and ii) privileging local search to global search, was superior to the GA.

The PSO was then used to estimate the parameters of all the models for each data group, and the results showed that the best OF values obtained for all the models except one (model 2A) were statistically equivalent to the variability of the experimental data. As for the concentrations predicted by the models, they all closely agreed with their experimental counterparts (goodness-of-fit coefficients close to 1), with the exception of glycerol and, in some instances, ethanol.

Model 1D was found to be the best model, considering both the OF values obtained for the two data groups and its reduced number of parameters. It was possible to provide an interpretation for the variation of its

parameters from one data group to the other, and formulate a testable hypothesis for the phenomena that took place, in terms of the different physiological pathways leading to biomass growth.

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João Estilita Antunes, "Hardware Architecture and Fast Deployment Methods for Soccer Robots", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: This thesis was geared towards integrating and developing new solutions that improve the reliability of the hardware architecture of soccer robots and its fast deployment on the field by the integration and development of calibration algorithms. The design steps of an hardware architecture appropriate for omnidirectional soccer robots are referred with special focus on the most important systems like the vision system, motor control and the kicker. Results of applications to real robots are presented.

Keywords: Soccer robots, hardware architecture, fast deployment, image processing, camera calibration, electromagnetic kicker.

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Hugo Augusto, "Navegação Autónoma e Percepção Cooperative Entre Robots Aéreos e Terrestres", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: In this thesis is described all the theoretical study and development options done on the scope of a project that aimed at the implementation of autonomous navigation with GPS on a team composed by an aerial and a land robot and the creation of a intelligent and cooperative decision solution for detection and exploration tasks on a topological map. We describe the theoretical and experimental development of a cooperative decision solution for an aerial and a land robot in a Search and Rescue contexts. The robots act as a team, and have to execute victim detection and exploration tasks. GPS is used to aid navigation in a topological map of the environment. To enable autonomous navigation, first we designed and implemented a PD controller in both robots, resulting in a control scheme with feedback of the position value as given a GPS sensor. After adjusting the control parameters, we simulated both solutions on the respective robots independently. Next, we created a model to allow the robots to detect points of interest in a map, and to cooperate using their navigational capabilities. The model uses a topological map representation of a map in the USARSim simulator, which consists of a graph with weighted edges corresponding to the traversal costs of each path in the map. These costs serve to formulate a shortest-path problem for the land robot to reach a point of interest. Based on a probabilistic cost uncertainty model, we designed a Markov decision process with belief states, which allowed solving the shortest path problem in the topological map. To conclude, we designed a set of scenarios for the team to operate in, the results of which we discuss.

Keywords: Multirobot systems, planning under uncertainty, blimps.

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André Dionísio Falcão, "Control of Depth of Anaesthesia using Locally Weighted Learning Methods", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: This dissertation addresses the control of depth of anaesthesia (DoA) with a novel approach. For control proposes DoA is modeled as a non-linear dynamic system. The approach consists in approximating the non-linear system by a set of locally linear systems obtained from one of two locally weighted learning methods: RFWR (Receptive fields weighted regression) or its most recent development LWPR (Locally weighted projection regression). The estimated local models are then used to synthesize local controllers that trough a controller fusion strategy, provide control to the the non-linear system. The main motivation for the proposed control strategy is to solve a real life problem involving the automatic administration of a drug that induces a certain degree of unconsciousness in a patient during surgery. The applications of the algorithms to the problem considered are explained and illustrated by simulation.

Keywords: Control, Adaptation, Learning, Anaesthesia, Biomedical Engineering, Multiple Models.

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Marco Gonçalo de Sousa Neves, "Auto-tuning de Controladores PID pelo método Relay: Optimização de Controlo em Automação Industrial", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: When completing the third year of experience in the section of industrial automation of department I&S-ES, of SIEMENS Portugal, my sensitivity for possible improvements, motivates me in the search of modern methods of industrial control. Being the great majority of the controllers used in the industry, PID controllers, my attention will be focused to the possible innovations/improvements that can introduce to them. Thus, the study of modern methods of auto-tuning will be part of this study, having as final objective, the development of automation tools, which will improve the dedicated time to the regulation of control systems. It is known that great part of PID controllers PID who play its role in the industry, make it below of its excellent regulation. These can be optimized by 2 ways, appealing the time consuming tests of regulation or through techniques of auto-tuning. After a brief study of some of the techniques of auto-tuning existing, the one that I considered more adequate to the use in processes of unknown and varied model and whose use does not intervene significantly with the productive process is known as "Relay Method". In this work, I study and implement an automatic technique for calibration of PID controllers that can have application to the majority of the systems of industrial control; The presented study will be enriched by my labor experience, where I constantly manage with development costs of development in the application of engineering solutions.

Keywords: Auto-Tuning, Automation, PID, Relay-Method.

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Nuno Moutinho, "Localização e Mapeamento Visual em Simultâneo: Detecção de Zonas de Aterragem", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: The development of autonomous systems has been growing throughout the years. The capacity systems have to, simultaneously, locate and map unknown environments, without any kind of human intervention, empowered the unknown's exploration evolution to levels never considered before. It is therefore necessary for this kind of system to have capabilities of action and decision in the required mission phases for which it was designed. The development of tools that can interact in the decision process of certain situations, constitutes an advance, bringing the systems closer to the desired autonomy level. However, complete autonomy is yet to be reached. The work presented on this thesis focus on the development of a simultaneous tracking and mapping system, which employs only one camera as a sensor. This system allows to determine the tridimensional movement completed by the specific camera and, estimate with a relative precision, the position of the reference points used in the process to locate itself. Furthermore, an algorithm was developed aiming for the detection of flat areas in the real world, using the previously obtained reference points, which can be considered feasible landing areas for aerospace vehicles. All the results showed in this thesis concern to simulations obtained in controlled environments, noting that the system was not implemented in real time.

Keywords: Localization, Mapping, Camera, Landing Areas.

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Diogo André Pires Vicente, "Event Detection with Pan-Tilt Cameras", M.Sc.Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: Although it is clear the intrinsic advantages of pan-tilt cameras with respect to fixed cameras, modern video surveillance systems are still based on networks of fixed cameras. It is patent that these equipments enclose great potential as surveillance instruments, but it is not yet clear the best approach for its insertion into automatic surveillance systems. The experiments detailed hereafter present relevant results enabling the use of these devices. In particular it focuses on: segmentation techniques, control modalities for the pan-tilt cameras, zoom impact on both types of algorithms, scenario representation and metrics for performance evaluation of event detection with pan and tilt cameras. Furthermore the metrics applied to evaluate performance results are extended from the state of the art for fixed camera scenarios to a pan-tilt scenarios. The results attained in the scope of this work rely in datasets generated from a virtual reality framework which was implemented to simplify the test images generation. This approach also eases the replication of experiments allowing a proper understanding of the results.

Keywords: Pan and Tilt Zoom Camera, Surveillance Systems, Event Detection, GroundTruth, Performance Evaluation, Metrics, Control Modalities.

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Jacinto Carlos Marques Peixoto do Nascimento, ISR/IST (co-supervisior)
Pedro Miguel Torres Mendes Jorge, ISEL

Nuno Miguel Pinto Leite, "Calibração de uma Rede de Câmaras baseada em Odometria Visual", M.Sc.Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: This work presents two methodologies to estimate the calibration of a network of cameras, possibly with non-overlapping fields of view. The calibration comprises both the intrinsic and extrinsic parameters of the cameras and is based on a mobile robot with the capability of estimating its pose in a global frame. The robot is equipped with one calibrated camera which we assume that can be oriented in a manner to observe world points also seen by the network of cameras. Our methodologies are based on matched scale invariant features (SIFT) reconstructed to 3D points using e.g. vSLAM, and focus on the problem of transporting the robot coordinate system to the fixed cameras. The reconstructed 3D points and their images on the fixed cameras are proposed as a solution for the calibration problem. In order to test the validity of our methodology we constructed a VRML scenario, thus having low noise images and ground truth information.

Keywords: Calibration, Networked Cameras, Factorization, Visual Odometry, SIFT, vSLAM.

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João Picão, "Development and Sea Tests Validation of an Acoustic USBL Positioning System", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: This work presents the study, development and at-sea testing of an Ultra Short Baseline (USBL) acoustic positioning system. An overview of existing acoustic positioning systems and corresponding operation modes is presented as well as background underwater acoustic concepts.
In the USBL system developed acoustic signal detection and time of arrival (TOA) estimation is based on the matched filter's output. Emitter's position is computed from the TOA of a known signal (expected signal) to four close-spaced hydrophones. In this way, system performance relies on accurate detection of the expected signal, which may be corrupted by additive noise and multipaths, and accurate TOA estimation. The traditional acoustic sine pulse is compared with a new class of coded, wide band signals (Spread Spectrum signals) that shows improved TOA resolution and stronger multipath and noise rejection and, for those reasons, will be used.
The use of SS signals and close-spaced hydrophones requires additional processing capability. Therefore, system implementation relies on real time digital signal processing of acquired data that allows for improved

performance and versatility. Digital matched filter implementation is based on Discrete Fourier Transform (DFT) and its properties.
A series of at-sea tests of this system have been conducted. Despite poor test site acoustic conditions (strong multipath and noise environment) the overall system behavior is considered to be satisfactory.

Keywords: acoustic positioning systems, USBL, spread spectrum signals, matched filter, digital signal processing.

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José Manuel Bioucas Dias

Ricardo Carona, "Visual Control Of Unicycle Type Robots", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: The research, described in the thesis, concerns the vision control of an unicycle type mobile robot. The problem is divided into four main components: robot modelling, robot control, pan-tilt camera control and image processing and filtering. The mathematical model of the mobile robots includes dynamics in the actuators. Motion control strategies, such as tracking and path following, are formulated. Two types of controllers found in the literature are revised and their performance is illustrated through computer simulations. The full system is developed considering indoor areas, with wide spaces, where the free motion of robots is allowed, in order to complete tasks as parking or group work following some target robot, i.e. a leader. Within the research, new techniques and original approaches are revealed. The robot control is based on a pan-tilt camera, whether most traditional systems favour fixed cameras. The main controller proposed is, advantageously, independent of the control strategy. An alternative approach to position tracking by the camera is also presented. A new communication interface is developed to allow the communication between systems using different communication protocols, namely YARP and TCP/IP. A calibration methodology for perspective cameras is proposed, including the conversion of the intrinsic parameters to the unusual format used by the Augmented Reality toolbox ARToolKit.

Keywords: Unicycle, path following, tracking, dynamics, camera, control, kalman filter, pan, tilt, YARP, ARToolKit.

Members of thesis committee:
Carlos Jorge Ferreira Silvestre, IST.
Jose Antonio da Cruz Pinto Gaspar, IST (supervisior).
Antonio Pedro Rodrigues de Aguiar, IST (co-supervisor).
Bertinho Manuel D'Andrade da Costa, IST.

Sérgio Carvalhosa, "Cooperative Motion Control of multiple autonomous robotic vehicles: Collision Avoidance in Dynamic Environments", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: The role of autonomous vehicles and robotics in aiding man in harsh environments has become an increasing focus of interest over the last decade, as the technology that enables this kind of systems becomes

available. A particular area that has received special attention, has been the study of coordination and control of various classes of unmanned autonomous vehicles. The main motivation for this trend is the wide range of military and civilian applications where teams of these vehicles working together exhibit better performance in terms of flexibility, robustness and efficiency compared to the single heavily equipped vehicle approach. For tasks such as space exploration, automated transport convoys, security patrols or large object transportation, having a cooperative team of vehicles provides for better area coverage as well has robustness to systems malfunctions. The completion of missions of this nature often requires holding a desired geometrical formation pattern, that is at the same time reactive and adaptive to an unknown environment, as for example to prevent imminent collisions.

It is in this framework that this thesis proposes a collision avoidance system to be integrated in a cooperative motion control (CMC) architecture, enabling the autonomous robotic vehicles that participate in a cooperative mission to automatically re-plan their trajectories in order to avoid unknown obstacles. The first part of the thesis describes the general architecture for CMC, that includes cooperative path following, where multiple vehicles are required to follow pre-specified spatial paths while keeping a desired inter-vehicle formation pattern. In the second part of the thesis we propose a Collision Avoidance system (CAS) that is composed by two subsystems: the collision prediction, and the collision avoidance module. For collision prediction we combine a bank of Kalman filters running in parallel, each using a different model for target motion, to derive an unknown object's velocity and estimate its probable trajectory, the vehicle pre-determined path is then checked for possible interactions with the obstacle. Collision avoidance is achieved either by controlling the speed of the vehicle along its assigned mission path, or through path re-planing using harmonic potential fields. Because group coordination must be taken into consideration, collision avoidance is implemented as part of a Behavior-based system, that is decentralized and can be used with groups of heterogeneous vehicles. The proposed collision avoidance system is then applied to a group of marine surface crafts, where simulation results are presented trough the use of a Cooperative Motion Control Simulator developed to model the key different aspects of cooperative multiple vehicle systems.

Keywords: Cooperative Motion Control, Collision Avoidance, Collision Prediction, Autonomous Surface Crafts, Potential field theory, Kalman filter, Coordinated path-following, Coordination control.

Members of the Thesis Committee:
Carlos Jorge Ferreira Silvestre
António Pedro Rodrigues de Aguiar
António Manuel dos Santos Pascoal
Miguel Afonso Dias de Ayala Botto

Fábio Silva, "Reconhecimento de padrões de Alzheimer em imagens PET", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, December 2009.

Abstract: Alzheimer's disease causes degenerative changes in nervous the tissue, which results in progressive loss of memory and cognitive functions. Alzheimer's disease is the most frequent type of dementia. The prevalence of Alzheimer's disease increases in the elderly patients, and given the fact that population is getting older it is expected that incidence increases. Currently, there is no cure for Alzheimer's disease, but early diagnosis and treatment can slow its progression.

The PET examination specifies the functional changes in the human brain and it is an useful tool in analyzing the cerebral blood flow. The regional abnormalities for Alzheimer's disease cause the reduction of blood flow, mainly the temporal lobe, parietal lobe and hippocampus. However, the difficulty of the analysis and interpretation of PET imaging in the diagnosis of Alzheimer's disease led to the use of methods of pattern recognition on PET imaging as a tool for automatic diagnosis of Alzheimer's disease.

In this dissertation, we used the *k*-nearest neighbor and Boosting methods in discrimination between the AD and Normal classes, MCI and Normal, and finally between the AD and MCI classes, with the purpose of making them a useful and effective tool in the automatic diagnosis of Alzheimer's disease. The implementation of the MCI class, rarely studied, allows the early diagnosis of Alzheimer's disease through the binary distinction between the MCI and Normal classes. Both methods are afflicted by the problem of "*curse of dimensionality*".
The Boosting method Adaboost achieved better performance than *k*-nearest neighbors method in all discrimination between classes. Thus, the Boosting method adapted better to the problem of "curse of dimensionality" and has serious potential to become a tool for automatic diagnosis of Alzheimer's disease.

Keywords: Alzheimer's disease, PET, automatic diagnosis, k-nearest neighbor, Boosting, Adaboost.

Members of the Thesis Committee:
Carlos Jorge Ferreira Silvestre
Maria Margarida Campos da Silveira
Jorge dos Santos Salvador Marques
Ana Luísa Nobre Fred

André Oliveira, "Software Architecture for Autonomous Vehicles", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

Abstract: This work details a complete software architecture for autonomous vehicles, from the development of a high-level multiple-vehicle graphical console, the implementation of the vehicles' low level critical software, the integration of the necessary software to create the vehicles' operating system, the configuration and building of the vehicles' operating system kernel, to the implementation of device drivers at the kernellevel, specifically a complete Controller Area Network subsystem for the Linux kernel featuring a socket interface, protocols stack and several device drivers.
This software architecture is fully implemented in practice for the Delfim and DelfimX autonomous catamarans developed at the Dynamical Systems and Ocean Robotics laboratory of the Institute for Systems and Robotics at Instituto Superior Tecnico. The DelfimX implementation is discussed and real profiling data of the vehicle's software performance at sea is presented, showing actuation response times under 100 microseconds for 99% of the time and 1 millisecond worst case with 10 parts-per million accuracy, using a standard Linux kernel.

Keywords: software, autonomous, Linux, DelfimX, CAN.

Members of the Thesis Committee:
José Bioucas Dias (DEEC/IST)
Luis Correia (DI/FC/UL)
Carlos Silvestre (DEEC/IST)

João F. P. Crespo, "A Multidimensional Companding Scheme for Source Coding with a Perceptually Relevant Distortion Measure", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Abstract: This thesis deals with the topic of multidimensional companding audio source coding. In this type of source coding, the vector source is passed by a pre-processing function, which we call the compressor, by a vector quantizer and finally, as a post-processing step, by the inverse of the preprocessing function, which we call the expander. Optimal multidimensional companding has the characteristic that locally quadratic distortion measures get mapped into the Mean Square Error (MSE) distortion measure in the compressed

domain. Multidimensional companding enables thus the efficient usage of quantization schemes designed for the MSE with locally quadratic distortion measures, if we use the optimal compressor and expander.
Recently, S. van de Par et al. developed a locally quadratic perceptual distortion measure for sinusoidal audio coding. In that work, the distortion is computed using a weighted MSE in the frequency domain, where the weights are given by the inverse of the masking threshold, a measure of the time-frequency dependent sensitivity of the human ear. This distortion measure has been successfully employed in several audio coding schemes.
In this thesis, we combine the technique of multidimensional companding with the mentioned perceptual distortion measure. The main contribution is the development of a multidimensional compander (compressor and expander), which is asymptotically optimal in the sense that it has a vanishing rate-loss with increasing vector dimension. The compressor operates in the frequency domain: in its simplest form, it point-wise multiplies the Discrete Fourier Transform (DFT) of the windowed input signal by the square-root of the inverse of the masking threshold, and then goes back into the time domain with the inverse DFT. The expander is based on numerical methods: we do one iteration in a fixed-point equation, and then fine-tune the result using Broyden's method.
Additionally, we show simulations which corroborate the approximations and results of the theoretical derivations.

Keywords: Multidimensional companding, locally quadratic distortion measure, perceptual distortion measure, sinusoidal audio coding

Members of the Thesis Committee:
José Manuel Bioucas Dias
Pedro Manuel Quintas Aguiar
Mário Alexandre Teles Figueiredo

Giovanni Saponaro, "Object Manipulation from Simplified Visual Cues", M.Sc. Thesis, Sapienza University of Rome, Italy, March 2009 (Co-Advisor Alexandre Bernardino).

Abstract: Humanoid robotics in general, and human-robot interaction in particular, is gaining new, extensive fields of application, as it gradually becomes pervasive in our daily life. One of the actions that humanoid robots must perform is the manipulation of things (reaching their arms for objects, grasping and moving them). However, in order to do this, a robot must first have acquired some knowledge about the target object and its position in space. This can be accomplished with a perceptual approach.
The developed system described in this thesis is based on the CAMSHIFT visual tracker and on a 3D reconstruction technique, providing information about position and orientation of a generic, model-free object that moves in the field of view of a humanoid robot platform. An object is perceived in a simplified way, by approximating it with its best-fit enclosing ellipse.
After having computed where an object is currently placed in front of it, the robotic platform can perform reaching tasks. Experiments obtained with the robot arm of the adopted platform are discussed.

Bruno Cardeira, "Architectures for Inertial/GPS Navigation with Application to Autonomous Vehicles", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, March 2009.

João Raminhos, "Acquisition of Electrophysiological Signal - Application to a mobile platform from the EOG signal", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, April 2009.

Indira Andrade, "fMRI Sparse Design for Auditive paradigms: Toward a Signal and Stimulus Perception Improvements", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, September 2009.

Bruno Afonso, "Music Classification - an Exhaustive Analysis of Automatic Genre Classification", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Hugo Pinto, "Robotized Microscopy", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Diogo Loureiro, "Web based robotized microscopy", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

André Baptista, "Continuous monitorization and automatic detection of cardiac abnormalities with mobile phone", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

Arantxa Oquina Barrio, "Modelling underwater acoustic noise as a tool for coastal management", M.Sc. Thesis, University of Algarve, Faro, Portugal, 2009.

João Domingos Pacheco, "Tracking People and Activities in Video Recordings of Classroom Presentations", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

Luis Filipe Rosado, "Sistema para Diagnóstico de Lesões Cutâneas Baseado em Imagens Dermos", M.Sc. Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

2.3.2 Theses in Progress during 2009

In this subsection the Doctoral and Master theses in progress during 2009, at ISR/IST (ECE) and ISR/Algarve (ECE), are identified and ordered by the scientific research area:

DOCTORAL THESES (62)

Research Area: Petri Net Based Modelling and Coordinated Execution of Robotic Tasks
Doctoral Student: Hugo Costelha
Advisor: Pedro Lima
Initiated: October 2003
Expected conclusion: 2010
Current Status: On-going, finished PhD coursework, candidacy exam passed
Grant: FCT (now finished)
Research Area: Multi-Agent Reinforcement Learning for Stochastic Games

Doctoral Student: Gonçalo Neto
Advisor: Pedro Lima
Initiated: October 2003
Expected conclusion: 2010
Current Status: On-going, finished PhD coursework, candidacy exam passed
Grant: FCT (now finished)

Research Area: Cooperative Perception
Doctoral Student: Abdolkarim Pahliani
Advisor: Pedro Lima
Initiated: February 2005
Expected conclusion: 2010
Current Status: On-going, finished PhD coursework
Grant: FCT

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, PhD coursework
Grant: FCT

Research Area: Planning under uncertainty for multi-robot systems
Doctoral Student: João Messias
Advisor: Pedro Lima, Matthijs Spaan
Initiated: September 2008
Expected conclusion: 2012
Current Status: On-going, PhD coursework
Grant: FCT

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, PhD coursework
Grant: FCT (IST/EPFL dual degree PhD program)

Research Area: Vision-based implicit communication for cooperative behaviours
Doctoral Student: Aamir Ahmad
Advisor: Pedro Lima
Initiated: September 2008
Expected conclusion: 2012

Current Status: On-going, PhD coursework
Grant: URUS project

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: FCT

Research Area: Computer Vision
Title: Recognition of Human Activities from video
Doctoral Student: Pedro Canotilho Ribeiro
Advisor: José Santos-Victor
Initiated: 2003
Expected conclusion: 2010
Current Status: On hold
Grant: FCT

Research Area: Computer Vision
Title: Biological inspired audio-visual learning.
Doctoral Student: Karl Jonas Hornstein
Advisor: José Santos-Victor
Initiated: 2005
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Computer Vision
Title: Learning in computer Vision
Doctoral Student: Bruno Damas
Advisor: José Santos-Victor
Initiated: 2007
Expected conclusion: 2010
Current Status: On-going

Grant: FCT

Research Area: Computer Vision
Title: Visual servoing.
Doctoral Student: Matteo Tajana
Advisor: Alexandre Bernardino
Initiated: 2008
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Computer Vision
Title: Visual Attention and space variant vision
Doctoral Student: Jonas Ruesch
Advisor: Alexandre Bernardino
Initiated: 2008
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Micro-robotics
Title: Micro robots for surgical intervention.
Doctoral Student: Ricardo Beira
Advisor: José Santos-Victor (IST), Hannes Bleuler (EPFL)
Initiated: 2005
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Micro-robotics
Title: Micro robots for surgical intervention.
Doctoral Student: Ricardo Beira
Advisor: José Santos-Victor (IST), Hannes Bleuler (EPFL)
Initiated: 2005
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Computer Vision
Title:
Doctoral Student: Dario Figueira
Advisor: Alexandre Bernardino
Initiated: 2009
Expected conclusion: 2013

Current Status: On-going
Grant: FCT

Research Area: Robotics
Title: Active Surveillance Using Robots.
Doctoral Student: Nelson Gonçalves
Advisor: João Sequeira
Initiated: 2002
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Underwater Acoustics
Title: N/A
Doctoral Student: Paulo Santos
Advisor: Paulo Felisberto (UAlg/ISR)
Initiated: 2007
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

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

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: 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

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

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)

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

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

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:
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

Research Area: Image Processing and Computer Vision
Title:
Doctoral Student: Rui F. C. Guerreiro
Advisor: Pedro M. Q. Aguiar
Initiated: 2008
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Computer vision
Title: Reconstruction of isometrically embedded flat surfaces from video sequences
Doctoral Student: Ricardo Ferreira
Advisor: João Paulo Costeira
Initiated: 2006
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Computer Vision
Title: Multiple Motion Segmentation.
Doctoral Student: Nuno Pinho da Silva
Advisor: João Paulo Costeira
Initiated: 2006
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Computer Vision
Title: Matching and reconstruction of rigid scenes
Doctoral Student: Manuel Ricardo Marques
Advisor: Joao Costeira
Initiated: 2007
Expected conclusion: 2011
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: 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: 2010
Current Status: Writing
Grant: EST-IPS

Research Area: Artificial Life – Evolutionary Systems
Title: Metodologias Evolucionistas na protecção e gestão de colheitas
Doctoral Student: Gong Hongfei
Advisor: Agostinho Rosa
Initiated: December 2003
Expected Conclusion: 2010
Current Status: thesis writing and final results

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: 2010
Current Status: on-going
Grant: FCT

Research Area: Dynamical Systems and Control
Title: Multiple Vehicle Cooperative Control
Doctoral Student: João Almeida
Advisor: Carlos Silvestre and António Pascoal
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Dynamical Systems and Control
Title: Control and Estimation of Impulsive Systems
Doctoral Student: Duarte Antunes
Advisor: Carlos Silvestre
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Navigation and Control Systems
Title: Sensor Based Navigation and Control of Autonomous Vehicles
Doctoral Student: Pedro Batista
Advisor: Carlos Silvestre and Paulo Oliveira
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Guidance, Navigation and Control
Title: Cooperative Navigation and Control of Autonomous Marine Vehicles
Doctoral Student: Pramod Maurya
Advisor: António Pascoal
Expected conclusion: 2012
Current Status: On-going
Grant: ISR and FCT

Research Area: Navigation and Positioning
Title: Navigation and Tracking Systems for Autonomous Vehicles
Doctoral Student: Mohammadreza Bayat
Advisor: António Aguiar
Expected conclusion: 2012

Current Status: On-going
Grant: FCT

Research Area: Nonlinear Observers
Title: Observers for Position and Autonomous Vehicle Position and Attitude Estimation
Doctoral Student: Sérgio Brás
Advisor: Carlos Silvestre and Paulo Oliveirda
Expected conclusion: 2010
Current Status: On-going
Grant: FCT

Research Area: Dynamical Systems and Control
Title: Motion Control of Autonomous Aerial Vehicles
Doctoral Student: David Cabeçinhas
Advisor: Carlos Silvestre
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Nonlinear Estimation, Sensor Fusion and Decision Systems
Title: Nonlinear Systems for Target Tracking and Navigation Aiding in Autonomous Robotics
Doctoral Student: Tiago Gaspar
Advisor: Paulo Oliveira
Expected conclusion: 2013
Current Status: On-going
Grant: FCT

Research Area: Control of autonomous vehicles
Title: Nonlinear model predictive control of autonomous vehicles in the presence of obstacles
Doctoral Student: Bruno Guerreiro
Advisor: Carlos Silvestre
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Control Theory
Title: Multiple Model Adaptive Estimation and Control
Doctoral Student: Vahid Hassani
Advisor: António Pascoal and Michael Athans
Expected conclusion: 2011
Current Status: On-going
Grant: ISR and FCT
Research Area: Multiple Vehicle Cooperative Motion Planning
Title: Multiple Vehicle Cooperative Mission Planning and Execution with Temporal and Energy Constraints

Doctoral Student: Andreas Hausler
Advisor: António Pascoal and António Aguiar
Expected conclusion: 2012
Current Status: On-going
Grant: Marie Curie FREESUBNetwork

Research Area: Underwater Positioning and Inertial Navigation Systems; Sensor fusion; Nonlinear estimation
Title: Inertial Navigation and Positioning Systems for Autonomous Marine Robots
Doctoral Student: Marco Morgado
Advisor: Paulo Oliveira and Carlos Silvestre
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Robust Adaptive Control
Title: Contributions to Robust Adaptive Control
Doctoral Student: Paulo Rosa
Advisor: Carlos Silvestre and Michael Athans
Expected conclusion: 2011
Current Status: On-going
Grant: FCT

Research Area: Dynamical Systems and Control
Title: Sensor Based Control of Multi-Rotor Aerial Vehicles
Doctoral Student: Pedro Serra
Advisor: Carlos Silvestre and Rita Cunha
Expected conclusion: 2012
Current Status: On-going
Grant: FCT

Research Area: Decision and Control Systems
Title: Analysis and Design of Complex Hybrid Dynamical Control Systems
Doctoral Student: Sérgio Pequito
Advisor: António Pedro Aguiar
Expected conclusion: 2014
Current Status: On-going
Grant: Program CMU-Portugal

MASTER THESES (28)

Research Area: Petri net models for Cooperative Robot Tasks
Student: Nuno Rodrigues
Advisor: Pedro Lima
Initiated: September 2009

Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: LTL Specifications for Petri net supervisors of robot tasks
Student: Manuel Biscaia
Advisor: Pedro Lima
Initiated: September 2009
Expected conclusion: 2010
Current Status: Delivered
Grant:

Research Area: Petri net models of individual behaviors
Student: Carlos Martins
Advisor: Pedro Lima
Initiated: September 2009
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Humanoid locomotion using a Bioloid platform
Student: Carlos Neves
Advisor: Rodrigo Ventura
Initiated: September 2008
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Blimp control and navigation using GPS
Student: Rui Nunes
Advisor: Rodrigo Ventura
Initiated: September 2009
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: TCS localization using laser-range finders in the ITER fusion reactor plant
Student: João Filipe Teles Ferreira
Advisor: Rodrigo Ventura, Alberto Vale
Initiated: September 2009
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Humanoid robot locomotion using the Bioloid platform
Student: Rodrigo Brito
Advisor: Rodrigo Ventura
Initiated: September 2008
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Planning under Uncertainty for Search and Rescue
Student: Ana Rita Mendes
Advisor: Matthijs Spaan and Pedro Lima
Initiated: 2008
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: POMDP models for active cooperative perception
Student: Tiago Veiga
Advisor: Matthijs Pedro Lima
Initiated: 2008
Expected conclusion: 2010
Current Status: On-going
Grant:

Title: Midleware for Dsitributed implementation on CELL architecture
Master Student: Bruno Martins
Advisor: Agostinho Rosa
Initiated: 2009
Expected Conclusion: 2010
Current Status: started
Grant: FCT

Title: Evolutionary Data Mining
Master Student: Luis Santos
Advisor: Agostinho Rosa
Initiated: 2009
Expected Conclusion: 2010
Current Status: started
Grant: FCT

Research Area: Medical Imaging
Title: Classificação de estados cognitivos em imagens FMRI com base em aprendizagem automática
Master Student: Carlos Cabral

Advisor: Margarida Silveira e Patricia Figueiredo
Initiated: 2009
Conclusion: 2010
Grant:

Research Area: Medical Imaging
Title: Diagnóstico da doença de Alzheimer com base em Imagens de MRI e PET
Master Student: Tânia Vaz
Advisor: Margarida Silveira e Jorge S. Marques
Initiated: 2009
Conclusion: 2010
Grant:

Research Area: Medical Imaging
Title: Segmentação de imagens usando Level sets
Master Student: Joana Baptista
Advisor: Margarida Silveira
Initiated: 2009
Conclusion: 2010
Grant:

Research Area: Biomedical Signal Processing and Acquisition
Title: Continuous ECG Acquisition Holter System with mobile phone
Masterl Student: Guilherme Carvalho
Advisor: João Sanches
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Medical Imaging – functionalMRI
Title: ASL Adaptive Optimal Sampling Strategy (AOSS)
Masterl Student: Miguel Rodrigues
Advisor: João Sanches and Patrícia Figueiredo
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Medical Image Processing
Title: Chromosome identification and pairing in optical microscopy images
Masterl Student: Guilherme Santos
Advisor: João Sanches and Rodrigo Ventura
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Biomedical Signal Processing
Title: Assessment of the cognitive deterioration in Sleep Apnea Syndrome by spectral analysis of physiological parameters.
Masterl Student: Ana Coito
Advisor: João Sanches and Teresa Paiva
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Medical Imaging – DCE MRI
Title: Hepatocarcinoma detection from DCE-MRI Images
Master Student: Nuno Barros
Advisor: João Sanches
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Medical Imaging – DCE MRI
Title: Estimation of the haemodynamic response to epileptic activity in EEG-fMRI data
Master Student: Marco Leite
Advisor: Patrícia Figueiredo and João Sanches
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Biomedical Signal Processing
Title: Biomedical Signal Processing, Storing and Transmitting by Mobile Phone
Master Student: Andreia Duarte
Advisor: João Sanches
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Biomedical Physiological Modeling /Physiology
Title: Modeling of the Haemodynamic Response Function based on Physiological Principles
Master Student: Ana Rita Gafaniz
Advisor: João Sanches
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Medical Imaging – functionalMRI
Title: Statistical Analysis and Detection of brain activated regions in functional MRI data, fMRI.
Master Student: Ricardo Maximiano

Advisor: João Sanches
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going

Research Area: Computer Vision
Title: Neural correlates on facial expressions in humans
Master Student: Ricardo Sousa
Advisor: João Rodrigues
Initiated: 2008
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Computer Vision
Title: Obstacle detection and avoidance on sidewalks
Master Student: João José
Advisor: Hans du Buf
Initiated: 2008
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Computer Vision
Title: Motion characterization though cortical optic flow
Master Student: Miguel Farrajota
Advisor: João Rodrigues
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Computer Vision
Title: Active vision for cognitive robot
Master Student: Mário Saleiro
Advisor: João Rodrigues
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going
Grant:

Research Area: Computer Vision
Title: Biological model of disparity
Master Student: Nuno Rosa

Advisor: Hans du Buf
Initiated: 2009
Expected conclusion: 2010
Current Status: On-going
Grant:

2.4 ADVANCED TRAINING

2.4.1 Courses

Alessio Del Bue, Adrien Bartoli, and Lourdes Agapito

- Computer Vision in a Non-Rigid World, Tutorial, ISR / IST, Lisbon, Portugal.

António Aguiar

- Nonlinear Control Systems.

António Pascoal

- Dynamical Systems and Optimization.

João Sanches

- Medical Imaging Reconstruction, Ph.D. Course, IST, Lisbon, Portugal.
- Digital Signal Processing, Joint Ph.D Programme on Fusion Science and Engineering, IST, Lisbon, Portugal.

Manuel Lopes, Luis Montesano, José Santos-Victor, Matthijs Spaan

- "RLSS09: Robot Learning Summer School", Mon 20 to Fri 24 July, 2009, Venue: Instituto Superior Técnico, Lisboa, Portugal, http://vislab.isr.ist.utl.pt/RLSS09/, IEEE Technical Com. on Robot Learning.

Orlando Camargo Rodríguez

- ESONET Training Workshop, Jacobs University, Bremen, Germany.

Paulo Oliveira

- Detection, Estimation, and Filtering.

Pedro Lima

- Autonomous Systems (4th year of Masters on Electrical and Computer Engineering, IST.
- Discrete Event Dynamic Systems (PhD Programme on Electrical and Computer Engineering).

Pedro Lima and João Sequeira

- Advanced Robotics (PhD Programme on Electrical and Computer Engineering), IST, Lisbon, Portugal.

Ruben Martinez-Cantin

- "Adaptive Sensing, Active Learning, and Experimental Design", held with NIPS 2009, organized by Rui Castro - Columbia University, Nando de Freitas - UBC, Ruben Martinez-Cantin, IST/ISR, Dec.11, 2009. http://nips.cc/Conferences/2009/Program/event.php?ID=1501.

2.4.2 Seminars

- **During 2009 the following Seminars were given outside ISR:**

Gustavo Carneiro

- "Database Guided Segmentation of Fetal Anatomies from 2-D/3-D Ultrasound Data using Sequential Sampling", Mestrado em Informática Médica, Ciclo de Palestras sobre Imagens Médicas, Faculdade de Cieências da Universidade do Porto. May 2009.

João Pedro Gomes

- "Comparative analysis of several modulation methods for underwater acoustic channels", Invited talk (by James Preisig) at the Woods Hole Oceanographic Institution, Woods Hole, MA - USA, May 13, 2009.
- "Simulating underwater acoustic propagation using the Acoustics Toolbox", Northeastern University, Boston, MA - USA, April 10, 2009.

Margarida Silveira

- "Level Set Segmentation of Dermoscopy Images", Ciclo de Palestras de Imagem Médica, Mestrado em Informática Médica, Faculdade de Ciências da Universidade do Porto, May 2009.

José Santos-Victor

- "Recent results in learning and development in humanoid robots", Khalifa University of Science and Technology. Dubai, United Arab Emirates, July 2009.
- "On Learning and Using Affordances with Humanoid Robots", Object-Action Complexes Workshop Humanoids, Paris, Dec. 2009.

- **ISR Regular seminars**

In a regular basis, and organized by António Pedro Aguiar, the following seminars were held:

"Character Recognition in Natural Images"
Dr. Teofilo De Campos
February 2009

"Fast Approximate Nearest Neighbors with Automatic Algorithm Configuration"
Marius Muja
February 2009

"Kalman and H Infinity Optimal Filtering for a Class of Kinematic Systems"
Pedro Batista, ISR/IST Ph.D. Student
February 2009

"Current research activities on Cognitive Architectures and Field Robotics at ISLab"
Rodrigo Ventura, ISR/IST
February 2009

"A Decision-theoretic Approach to Dynamic Sensor Selection in Camera Networks"
Matthijs Spaan, ISR/IST
March 2009

"Underwater Acoustic Communications at the Intersection of Physical Oceanography, Acoustics, and Signal Processing"
James Preisig, Woods Hole Oceanographic Institution
March 2009

"The RobotCub Project: Humanoid Robots as tools for understanding Cognition"
José Santos-Victor, ISR/IST
March 2009

"Weights optimization for consensus algorithm in the presence of random link failures"
Dusan Jakovetic, ISR/IST Ph.D. Student
March 2009

"Tutorial on Computer Vision in a Non-Rigid World: Conclusions and Discussion"
Alessio Del Bue, ISR/IST
April 2009

"Towards a Unified View of Communication and Control & New Results in Nonlinear Estimation"
Prof. Sanjoy Mittera, MIT
April 2009

"Affordance based word-to-meaning association"
Verica Krunic, ISR/IST
May 2009

"Self-Assembly, Morphology Control and Firefly-Inspired Fault Detection in a Swarm of Autonomous Robots"
Anders Lyhne Christensen
May, 2009

"Sensor selection for hypothesis testing in wireless sensor networks: a Kullback-Leibler based approach"
Dragana Bajovic, ISR/IST Ph.D. Student
May 2009

"Inference and Learning for Active Sensing, Experimental Design and Control"
Ruben Martinez-Cantin, ISR/IST
May 2009

"Stability of Impulsive Systems driven by Renewal Processes"
Duarte Antunes, ISR/IST Ph.D. Student
June 2009

"What Agents Can Probably Enforce (joint work with Nils Bulling)"
Wojtek Jamroga, University of Luxembourg
June 2009

"Introducing fuzzy decision stumps in boosting through the notion of neighborhood"
Plinio Moreno López, ISR/IST
June 2009

"Learning Optimal Representations for Human Sensing"
Fernando De la Torre, Research Assistant Professor, Robotics Institute, Carnegie Mellon University
July 2009

"Decentralized Low Communication 6DoF Full State Formation Navigation"
Sónia Marques, ISR/IST Ph.D. Student
July 2009

"Collaborating Swarms, Network Topologies and Constrained Coalitional Games"
John S. Baras, University of Maryland College Park
July 2009

"Single Range Navigation in the presence of Constant Unknown Drifts"
Pedro Batista, ISR/IST Ph.D. Student
October 2009

"Recent advances on aiding techniques for USBL Tightly-Coupled Inertial Navigation Systems"
Marco Morgado, ISR/IST Ph.D. Student

2.4.3 Visits Abroad

Gustavo Carneiro

- Visited Prof. Luiz Velho – Instituto de Matemática Pura e Aplicada, Rio de Janeiro, RJ, Brasil, August - 2009.
- Visited Prof. Eliana Aude – Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brasil, August - 2009.

João Pedro Gomes

- Department of Electrical Engineering, Northeastern University, Boston, USA, March - June 2009 (on sabbatical leave, visiting Prof. Milica Stojanovic).
- Department of Electrical and Computer Engineering, Carnegie-Mellon University, Pittsburgh, PA - USA, October 2009 (exploratory meetings within the CMU-PT programme).

João Xavier

- Carnegie Mellon University (CMU), November 2009.

Dynamical Systems and Ocean Robotics Lab
Several visits abroad in the scope of long standing cooperation links that include the following:

- Department of Mechanical Engineering and Aeronautics, Naval Postgraduate School,Monterey, CA (USA) – a long standing collaborative research program on AUV and UAV Navigation, Guidance, and Control (NGC) as well as cooperative multiple vehicle path planning and control with temporal and spatial deconfliction.
- Center for Control, Dynamical Systems, and Computation (CCDC) at University of California, Santa Barbara, CA (USA) – joint work on control, estimation theory, and networked control systems.
- National Institute of Oceanography (NIO), Goa (India) – an intensive research and development program was initiated in 1999, leading to the development of the MAYA AUV.
- Department of Engineering Cybernetics, Norwegian University of Science and Technology (NTNU), Trondheim (Norway) – exchange of students and research personnel; jont work on cooperative path following control.
- University of Girona, Institute of Informatics and Applications, Escola Politècnica Superior, Girona (Spain) – joint theoretical and practical work on Mission Control Systems for autonomous underwater vehicles.
- Dept. Mechanical Engineering, John Hopkins University, Baltimore (USA) – exchange of research personnel and joint initiatives on Underwater Navigation Systems.

- Laboratoire I3S - Laboratoire d'Informatique, Signaux et Systèmes Centre National de Recherche Scientifique, de Sophia-Antipolis, NICE France. Exchange of research personnel and joint initiatives on Sensor Based Control for Unmanned Air Vehicles.
- Dept. Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh (USA) - exchange of research personnel and joint initiatives on Analysis and Design of Complex Hybrid Dynamical Control Systems.

2.4.4 Reading Groups

VisLab weekly seminar meeting.

Monthly seminars: Brain Imaging Interest (SIPG)

2.4.5 Supervision of Students Enrolled in Foreign Universities

Carlos Silvestre

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

Gustavo Carneiro

- Co-Supervisor of Michael Wels, Ph.D. Student from Friedrich-Alexander University Erlangen-Nuremberg. Erlangen, Germany.

João Sanches

- Erasmus, Ph.D. Student - Ondrej Adamec, Department Measurement and control / Faculty of Electrical Engineering and Computer Science, VSB – TU Ostrava, Czech Republic.

Margarida Silveira

- Supervisor of Dário Oliveira, Master's Student from Pontifícia Universidade Católica do Rio de Janeiro, Brasil – three month period at ISR/IST, December 2008 to February 2009.
- Supervisor of Masaaki Yasui, Master's Student from The University of Tokyo, Tokyo, Japan, three month period at ISR/IST, September 2009 to November 2009.

Pedro Lima

- Co-Supervisor of Valdinei Silva, Ph.D. Student from Universidade Politécnica de São Paulo, Brasil.

2.5 CONGRESS, MEETINGS AND PRESENTATIONS

This section includes invited talks, conferences attended and conferences where papers were presented, during 2009, by ISR-Lisbon researchers.

2.5.1 Invited Talks

Agostinho Rosa

- "Análise do EEG do Sono", curso de Mestrado em ciência do sono, IMM-FMUL, November 2009.
- "Som e Imagem por Evolução Artificial", Faculdade de Ciências da Universidade de Lisboa, December 2009.
- "Complexidade Evolutiva", Encontros de Emergência e Complexidade, September 2009.
- "Evolução Artificial", Colóquio Sociedades Humanas e Sociedades Artificiais, March 2009.

António Aguiar

- "State Estimation of Systems with Implicit Outputs: A minimum energy approach," Carnegie Mellon University (CMU), Pittsburg, PA, January 2009.
- "Minimum energy state estimation for nonlinear systems," Workshop on The Interface Between Mathematics, Science and Engineering, Porto, PT, May. 2009.
- "Guidance, Navigation, and Control of Autonomous Marine Vehicles," Invited Lecture, The Euro Mediterranean Incubator of the e-Business Management, University of Salento, Lecce, Italy, July 2009.

António Pascoal

- "Marine Science and Technology: a Vision of the Future". An invited lecture at SERI (Salon Européen de La Recherche et de L´Innovation), Paris, France, 5 June 2009.
- "Technologies and Systems for Ocean Monitoring and Exploration," Invited Lecture, Science Meetings 2009 (a meeting of the key research institutions in Portugal, organized by the Ministry of Science and Technology, Lisbon, July 2009.
- "Cooperative Control of Multiple Autonomous Vehicles for Ocean Exploration: Mission Scenarios, Theoretical Foundations, and Practical Issues," Plenary Lecture, 2009 Korea Automatic Control Conference (KACC2009), Busan, South Korea, 3 September 2009.
- "Cooperative Control of Multiple Autonomous Vehicles," Invited Talk, Workshop on Ocean Systems Control, Univ. S Paulo (USP), S. Paulo, Brazil, 16 September 2009.

Carlos Silvestre

- "Control and Navigation of Aerial and Marine Vehicles," Laboratoire I3S - Laboratoire d'Informatique, Signaux et Systèmes Centre National de Recherche Scientifique, de Sophia-Antipolis, Nice, France, November 2009.

João Pedro Gomes

- "Comparative analysis of several modulation methods for underwater acoustic channels", Invited talk (by James Preisig) at the Woods Hole Oceanographic Institution, "Woods Hole, MA, USA, May 13, 2009.
- "Simulating underwater acoustic propagation using the Acoustics Toolbox", Northeastern University, Boston, MA - USA, April 10, 2009.

João Sanches

- "Tissue Characterization by Image Analysis for Diagnostic Purposes", Ciência 2009, Encontro com a Ciência em Portugal, 29-30 de Julho, Fundação Gulbenkian, Lisboa.

Matthijs Spaan

- "Decision-theoretic Planning under Uncertainty for Active Cooperative Perception", Linköping University, Sweden, Oct 2009, and Örebro University, Sweden, Nov 2009.

Orlando Camargo Rodríguez

- "Tomografia Acústica Submarina: monitorização acústica dos oceanos" Invited Talk, *OMARSAT*, Arraial do Cabo, Rio de Janeiro, Brasil, 10-12 November 2009.
- "Modelação acústica submarina de alta frequência baseada em traçamento de raios: revisão teórica e aplicações actuais" Invited Talk, *ETASVIII*, Rio de Janeiro, Rio de Janeiro, Brasil, 25-27 November 2009

Paulo Oliveira

- "Survey Data Interpolation and Terrain Reference Navigation Supported on Principal Component Analysis," Invited talk at the Workshop on Marine Intelligence for Autonomous Operations, Lericci, Italy, October 2009.

Porfírio Silva

- "Vida Institucional Artificial", Conference Series "From Human Societies to Artificial Societies" (Das Sociedades Humanas às Sociedades Artificiais), 2009 edition), Institute for Systems and Robotics (Instituto Superior Técnico), March 26.
- "Fabulous Races of Humanoid Monsters and Robots", "Geschichte(n) der Robotik" (Histories of Robots), Jahrestagung der Gesellschaft für Technikgeschichte (The Society for the History of Technology, Germany, Annual Meeting), May 22-24.
- "Institutional Environments and Artificial Societies", International Conference "Darwin and the Social Sciences", Instituto de Ciências Sociais da Universidade de Lisboa, June 3-4.
- "Institutional facts: a concept to organize some discussions on comparative social cognition in animals, robots and humans", Contribution to the session "Interaction with humans in robots and animals", Discussion Meeting "Comparative Cognition including non-biological species: robots and animals", CompCog Research Networking Programme funded by the European Science Foundation, Léon, Spain, May 28-29.

2.5.2 Participations

AAAI FS 2009 – AAAI Fall Symposium, Arlington, Virginia, USA, November 2009.

AAMAS 2009 - International Conference on Autonomous Agents and Multi-Agent Systems, Budapest, Hungary, May 2009.

ACC 2009 – American Control Conference, St. Louis, Missouri, USA, June 2009.

ACII 2009 - International Conference on Affective Computing & Intelligent Interaction, Amsterdam, Netherlands, September 2009.

BCCN 2009 - Bernstein Conference on Computational Neuroscience, Frankfurt am Main, Germany, 30 Sept. - 2 Oct, 2009.

CDC 2009 – 48th IEEE Conference on Decision and Control, Shanghai, China, December 2009.

CLAWAR 2009 – International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, Istanbul, Turkey, September 2009.

COMPIT 2009 – 8th International Conference on Computer Applications and Information Technology in the Maritime Industries, Budapest, Hungary, May 2009.

DSAI 2009 - International Conference on Software Development for Enhancing Accessibility and Fighting Info-exclusion, Lisbon, Portugal, June 3-5, 2009.

ECC 2009 – European Control Conference, Budapest, Hungary, August 2009.
ECVP 2009 - European Conference on Visual Perception , Regensburg, Germany, August 24-28, 2009.

EPIA 2009 – 14th Portuguese Conference on Artificial Intelligence, Aveiro, Portugal, October 2009.

ETFA 2009 – 14th IEEE International Conference on Emerging Technologies and Factory Automation, Mallorca, Spain, September 2009.

EUSIPCO 2009 - The 17th European signal processing conference, Glasgow, Scotland, August 2009.

HBM 2009 - 15th Annual Meeting of the Organization for Human Brain Mapping, June 18-23, San Francisco, California, 2009.

IbPRIA 2009 - 4th Iberian Conference on Pattern Recognition and Image Analysis, Póvoa de Varzim, Portugal, June 10-12, 2009.

ICAPS 2009 – 19th International Conference on Automated Planning and Scheduling, Thessaloniki Greece, September 2009.

ICIP 2009 - IEEE International Conference on Image Processing, Cairo, Egypt, November 2009.

IJCAI 2009 - International Joint Conference on Artificial Intelligence, Pasadena, CA, USA, July 2009.

ISWCS 2009 - 6th IEEE Symposium on Wireless Communication Systems, Sienna, Italy, September 2009.

KDIR 2009 - International Conference on Knowledge Discovery and Information Retrieval, Funchal, Portugal, 2009.

MED 2009 – 17th Mediterranean Conference on Control and Automation, Thessaloniki, Greece, June 2009.

MCMC 2009 – 8th Conference on Manoeuvring and Control of Marine Craft, Guarujá, SP, Brazil, September 2009.

NESTER 2009 - Workshop on Networked embedded and control system technologies: European and Russian R&D cooperation, Milan, Italy, July 2009.

Oceans 2009 MTS/IEEE Conference on Oceanic Engineering, Biloxi, Mississippi, USA, October 2009.

RoboCup 2009, Graz, Austria, June 29 –July 5 2009.

ROBOTICA 2009 - 9th Conference on Autonomous Robot Systems and Competitions, Castelo Branco, Portugal, May 2009.

SPARS 2009 - International Workshop on Signal Processing with Adaptive Sparse Structured Representations, Saint-Malo, France, April 2009.

VISAPP 2009 - International Conference on Computer Vision, Theory and Applications, Lisbon, Portugal, February 2009.

1st REP10 meeting, NURC, La Spezia, Italy, 30-31 March & 1 April 2009 (Paulo Felisberto).

2nd ICT Coordinators Day on Project Management in FP7, INFSO-EU, Brussels 10 June 2009 (Paulo Felisberto).

2.6 SERVICE ACTIVITIES

This section is dedicated to service activities developed, during 2009, 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.
- Member of the Editorial Board of the International Journal of Web-based Learning and Teaching Technologies.

António Pascoal

- Associate Editor, IEEE Oceanic Engineering.

Hans du Buf

- Associate Editor of the International Journal of Pattern Recognition and Artificial Intelligence (IJPRAI)

Jorge S. Marques

- Associate Editor of Statistics and Computing Journal, Springer.

Mathhijs Spaan

- Guest editor of Special issue on "Signal Processing Advances in Robots and Autonomy", EURASIP Journal on Advances in Signal Processing (2009).

Pedro Lima

- Member of the Editorial Advisory Board of Journal of Advanced Robotic Systems, published by ARS Publishing, Vienna.
- Member of the Editorial Board of the Portuguese Magazine Robótica.

2.6.2 Advisory Boards

Agostinho Rosa

- Member of AWBL – Advances in Web Based Learning Book Series – (2007-2009).

António Pascoal

- Vice-President of EurOcean, the European Portal for Marine Science and Technology.
- Member, European Science Foundation (ESF) pannel in charge of evaluating the Bulgarian Academy of Sciences, 2009.

Gustavo Carneiro

- Unity Through Knowledge Fund - Croatia.

Isabel Ribeiro

- Vice-Chair of the Technical Committee on Intelligent Autonomous Vehicles of IFAC.

João Sanches

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

José Santos-Victor

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

Pedro Lima

- Member of the Steering Committee of Critical Challenge, initiative promoted by Critical Move, within the framework of the MIT-Portugal program, with the support of FCT (http://www.criticalchallenge.com).

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.

Alexandre Bernardino

- Program Committee Member, EPIROB 2009 - International Workshop on Epigenetic Robotics.
- Program Committee Member, ICIAR2009 - International Conference on Image Analysis and Recognition.

António Aguiar

- Member of the IFAC Technical Committee on Intelligent Autonomous Vehicles.
- International Program Committee Member for the IFAC Conference on Manoeuvering and Control of Marine Craft (MCMC'09).
- International Program Committee Member for the IEEE International Conference on Control Applications (CCA2009).

António Pascoal

- Chair, IFAC Technical Committe on Marine Systems.
- Member of the IFAC Technical Committee on Intelligent Autonomous Vehicles.
- Chair, International Program Committee, MCMC 2009 (Maneuvering and Control of Marine Craft) Conference, Guarujá, Brazil.
- Convener and Member of the Organizing Committee, Workshop "Networked embedded and control system technologies: European and Russian R&D cooperation", Milan, Italy, July 4-5, 2009.
- Guest Editor, Special Session on Marine Robotics, ICRA 2010.

Carlos Silvestre

- Member of the International Technical Committee of the 8th IFAC Conference on Manoeuvering and Control of Marine Craft - MCMC, Guarujá, Brazil, September 2009.

Hand du Buf

- MDA - International Conference on Mass Data Analysis of Images and Signals in Medicine,
- Biotechnology and Chemistry.
- CAIP - International Conference on Computer Analysis of Images and Patterns.
- CIARP - Iberoamerican Congress on Pattern Recognition.
- WSCG - Int. Conf. in Central Europe on Computer Graphics, Visualization and Computer Vision.

Gustavo Carneiro

- International Conference on Computer Vision (ICCV)
- IEEE Conference on Computer Vision and Pattern Recognition (CVPR)
- Canadian Conference on Computer and Robot Vision (CRV)
- Asian Conference on Computer Vision (ACCV)
- International Conference on Computer Vision Theory and Applications (VISAPP)

João Pedro Gomes

- 4th ACM international workshop on underwater networks (WUWNet'09), Berkeley, California, USA, November 3, 2009.

João Sanches

- ISBI 2009 - IEEE International Symposium on Biomedical Imaging.
- MED 2009 - 17th Mediterranean Conference on Control and Automation.
- CIARP 2009 - Iberoamerican Congress on Pattern Recognition.
- EMBC 2009 - Conference of the IEEE Engineering in Medicine and Biology Society.
- ICIAR 2009 - International Conference on Image Analysis and Recognition.
- IECON 2009 - Conference of the IEEE Industrial Electronics Society.

Jorge S. Marques

- Member of the Program Committee of CAEPIA 2009 – Conferencia de la Asociacion Española para la Inteligencia Artificial, Seville, 2009.
- Member of the Program Committee of AVSS 2009 - IEEE International Conference on Advanced Video and Signal Based Surveillance, Genova, 2009.
- Member of the Program Committee of IbPRIA 2009 – Iberian Conference Pattern Recognition and Image Analysis, Póvoa do Varzim, June, 2009.
- Member of the Program Committee of VIIP 2009 – Visualization, Imaging and Image Processing, Cambridge, July 2009.
- Member of the Program Committee of Ecomas Tematic Conference on Computational Vision and Medical Image Processing, 2009.

José Santos-Victor

- Program Committee Member, ICRA 2009 - IEEE International Conference on Robotics and Automation.
- Program Committee Member, CVPR 2009 - IEEE Computer Society Conference on Computer Vision and Pattern Recognition.
- Program Committee Member, IROS 2009 - IEEE International Conference on Intelligent Robots and Systems.
- Program Committee Member, RSS 2009 - Robotics Systems and Science.

Luis Montesano

- Robotics: Science and Systems.

Manuel Lopes

- Robotics: Science and Systems.
- International Conference on Development and Learning.

Matthijs Spaan

- Programme Committee Member, AAMAS 2009 – 8th International Conference on Autonomous Agents and Multi-Agent Systems, Budapest, Hungary, May 2009.

- Programme Committee Member, IJCAI 2009 – 21st International Joint Conference on Artificial Intelligence, Pasadena, California, USA, July 2009.
- Programme Committee Member, ICAPS 2009 - 19th International Conference on Automated Planning and Scheduling, Thessaloniki, Greece, September 2009.

Paulo Felisberto

- Member of the Technical Program Committee of the Third International Conference on Sensor Technologies and Applications SENSORCOMM 2009, Athens/Glyfada, Greece, June 18-23, 2009.

Paulo Oliveira

- Member of the International Technical Committee of the 17th European Signal Processing Conference - EUSIPCO 2009, Glasgow, Scotland, 24-28 August 2009.
- Member of the International Technical Committee of the 8th IFAC Conference on Manoeuvering and Control of Marine Craft - MCMC, Guarujá, Brazil, September 2009.
- Member of the International Technical Committee of IROBOT'2009 Thematic Track on Intelligent Robotics, a track of EPIA'2009 - Portuguese Conference on Artificial Intelligence, Aveiro, Portugal, October 2009.

Pedro Aguiar

- Member of the Technical Program Committee of the IEEE International Conference on Image Processing, Cairo, Egypt, November 2009.
- IEEE International Conference on Acoustics, Speech, and Signal Processing ICASSP'09, Taipei, Taiwan, April 2009.

MRLab researchers were IPC members of the following conferences:

- ROBOTICA 2009 - Scientific Meeting of the Portuguese Robotics Festival, Castelo Branco, Portugal, May 2009.
- SAFEPROCESS 2009 - 7th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes, Barcelona, Spain, June 2009.
- ICINCO 2009 – 6th International Conference on Informatics in Control, Automation and Robotics, Milan, Italy, July 2009.
- IROBOT 2009 - 4th International Workshop on Intelligent Robotics, integrated in the 12th Portuguese Conference on Artificial Intelligence – EPIA 2009, Aveiro, Portugal, October2009.
- IECON 2009 - 35th Annual Conference of the IEEE Industrial Electronics Society, Porto, Portugal, November 2009.
- SSRR 2009 - IEEE International Workshop on Safety, Security, and Rescue Robotics, University of Denver, Denver, Colorado, USA, November 2009.

2.6.4 Chairperson

Agostinho Rosa

- Program Chair, ICEC 2009 - International Conference of Evolutionary Computation, Funchal, Madeira, October 2009.
- Track Chair, SAC 2009 – 24th ACM Symposium on Applied Computing, Special Track on the Computational Intelligence and Image Analysis (CIIA), Honolulu, Hawaii, March 2009.
- Thematic track Chair, ALEA 2009 – Artificial Life and Evolutionary Algorithms, part of the EPIA 2009 – 14th Portuguese Conference on Artificial Intelligence, Aveiro, Portugal, October 2009.

António Aguiar

- Chair of the session "Ship Manoeuvring II", MCMC 2009, Guarujá (SP), Brazil, September 2009.
- Co-Chair of the session "Sensors and Sensor Integration in Autonomus Robots", MCMC 2009, Guarujá (SP), Brazil, September 2009.

António Pascoal

- Co-chair of the session on Deep-Sea Technology and Biotechnology Research, ICES Symposium Issues Confronting the Deep Oceans: The Economic, Scientific, and Governance Challenges and Opportunities of Working in the Deep Sea Amor da Pátria Hall, Horta, Faial Island, Azores, Portugal, April 27 – 30, 2009.
- Chair of the session "Overview of underwater systems: from manned submersibles to AUVs", MCMC 2009 - 8th Conference on Manoeuvring and Control of Marine Craft, Guarujá, SP, Brazil, September 2009.
- Chair of the session "Cooperative navigation and control of Multiple Marine Vehicle Systems", MCMC 2009 - 8th Conference on Manoeuvring and Control of Marine Craft, Guarujá, SP, Brazil, September 2009.

Carlos Silvestre

- Chair of the session "Robust Adaptive Control", ACC 2009 - American Control Conference, St. Louis, Missouri, USA, June 10 - 12, 2009.
- Co-Chair of the session "Time Varying Systems", ACC 2009 - American Control Conference, St. Louis, Missouri, USA, June 10 - 12, 2009.
- Co-Chair of the session "Estimation II", ACC 2009 - American Control Conference, St. Louis, Missouri, USA, June 10 - 12, 2009.
- Co-Chair of the session "Observers I", ECC 2009 - European Control Conference, Budapest, Hungary, August 23-26, 2009.
- Chair of the session "Advanced Nonlinear Control Techniques for Unmanned Air Vehicles", CDC 2009 - 48th IEEE Conference on Decision and Control, Shanghai, China, December 2009.
- Carlos Silvestre and Tarek Hamel special session on "Advanced Nonlinear Control Techniques for Unmanned Air Vehicles", CDC 2009 - 48th IEEE Conference on Decision and Control, Shanghai, China, December 2009.

João Sequeira

- Chair of session, SSRR 2009 - IEEE International Workshop on Safety, Security, and Rescue Robotics, University of Denver, Colorado, USA, 2009.

Matthijs Spaan

- Chair, AAMAS 2009 Workshop on Multi-Agent Sequential Decision Making in Uncertain Domains, Budapest, Hungary, May 2009.

Rodrigo Ventura

- Co-chair of Special session, ACII 2009 - International Conference on Affective Computing & Intelligent Interaction, Amsterdam, The Netherlands, September 2009.
- Co-chair of Panel, AAAI Fall Symposium 2009, Arlington, Virginia, USA, November 2009.

2.6.5 Reviewers

Agostinho Rosa

- BSPC Biomedical Signal Processing & Control.
- IEEE Transactions on Computational Intelligence and Artificial Intelligence in Games.
- SAC 2009 – The 24th Annual ACM Symposium on Applied Computing.
- BMIC 2009 – The 3rd International Syposium on Bio- and Medical Informatics and Cybernetics.
- ICINCO 2009 – The 6th International Conference on Informatics in Control, Automation and Robotics.

Alexandre Bernardino

- Autonomous Robots, Springer Netherlands.
- International Journal on Humanoid Robot, World Scientific.
- IEEE Transactions on Image Processing.
- IEEE Transaction on Robotics.
- ECCV 2009 - European Conference on Computer Vision.
- EPIROB 2009 - The International Workshop on Epigenetic Robotics.
- ICIAR 2009 - International Conference on Image Analysis and Recognition.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.

António Pascoal, Carlos Silvestre, Paulo Oliveira, and António Aguiar – reviewers for a large number of journals and conferences that include:

- IEEE Transactions on Automatic Control
- Elsevier AUTOMATICA
- IEEE Transactions on Oceanic Engineering
- IEEE Control Systems Technology
- International Journal of Robust and Nonlinear Control
- ACC 2009 - American Control Conference
- CDC 2009 - IEEE Conference on Decision and Control
- ISIT 2009 - IEEE International Symposium on Information Theory
- ICRA 2009 - IEEE International Conference on Robotics and Automation
- ASCC 2009 - Asian Control Conference.
- MSC 2009 - IEEE Multi-conference on Systems and Control.

Gustavo Carneiro

- IEEE Transaction on Pattern Analysis and Machine Intelligence.
- IEEE Transactions on Image Processing.
- IEEE Transactions on Medical Imaging.
- Image and Vision Computing
- Pattern Recognition
- IEEE Transactions on Systems, Man and Cybernetics, Part B.
- EURASIP Journal on Advances in Signal Processing.
- International Journal of Pattern Recognition and Artificial Intelligence.

Hans du Buf

- IEEE Trans. Pattern Analysis and Machine Intelligence.
- IEEE Computer Vision.
- IEEE Image Processing, Signal Processing.
- IEEE Trans. Systems, Man, and Cybernetics.

- Pattern Recognition.
- Pattern Recognition Letters.
- IJPRAI.
- Biological Cybernetics.
- MDA - Int. Conf. on Mass Data Analysis of Images and Signals in Medicine.
- Biotechnology and Chemistry.
- CAIP - Int. Conf. on Computer Analysis of Images and Patterns.
- CIARP - Iberoamerican Congress on Pattern Recognition.
- WSCG - Int. Conf. in Central Europe on Computer Graphics, Visualization and Computer Vision.

Isabel Ribeiro

- Robotica 2009.
- Safeprocess 2009 – 7th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes.
- IROBOT 2009 - 4th International Workshop on Intelligent Robotics, held at EPIA 2009.
- IECON 2009 - 35th Annual Conference of the IEEE Industrial Electronics Society.

João Pedro Gomes

- IEEE Journal of Oceanic Engineering.
- Journal of the Acoustical Society of America.
- IET Electronics Letters.
- IEEE transactions on signal processing.
- IEEE transactions on vehicular technology.
- IEEE transactions on computers.
- ACM transactions on embedded computing systems (TECS).
- Journal of Zhejiang university – Science A (ZUSA).
- Journal of the electronics and telecommunications research institute (ETRI);
- ACM International Workshop on UnderWater Networks (WUWNet 2009).
- MTS/IEEE Oceans 2009.
- International conference on robotics and automation (ICRA 2010).
- SENSORCOMM'09 international conference.
- IEEE/RSJ international conference on intelligent robots and systems (IROS 2009).

João Rodrigues

- DSAI - Int. Conf. on Software Development for Enhancing Accessibility and Fighting Info-exclusion.

João Sanches

- IEEE Transactions on Biomedical Engineering.
- EURASIP Journal on Advances in Signal Processing.
- SIVP Signal, Image and Video Processing.

João Sequeira

- IEEE Transactions on Instrumentation and Measurement.
- IEEE Transactions on Intelligent Transportation Systems.
- Journal of Advanced Robotics 2009.
- Journal of Robotics.
- ECC 2009 - European Control Conference.
- ICINCO 2009 – The 6th International Conference on Informatics in Control, Automation and Robotics.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.

- IECON 2009 - 35th Annual Conference of the IEEE Industrial Electronics Society.
- IROS 2009 - IEEE/RSJ International Conference on Intelligent Robots and Systems.
- MED 2009 – 17th Mediterranean Conference on Control and Automation.
- Robotica 2009
- SSRR 2009 - IEEE International Workshop on Safety, Security, and Rescue Robotics.

José Gaspar

- CVIU, Computer Vision and Image Understanding, Journal, Elsevier.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.
- IROS 2009 - IEEE/RSJ International Conference on Intelligent Robots and Systems.
- SIMPAR 2009 - International Conference on Simulation, Modeling and Programming for Autonomous Robots.

José Santos-Victor

- IEEE Transactions on Pattern analysis and Machine Intelligence.
- IEEE Transactions on Robotics and Automation.
- IEEE Transactions on Biomedical Engineering.
- IEEE Transactions on Robotics.
- IEEE Transactions on System Man and Cybernetics.
- Journal of Robotics and Autonomous Systems.
- BMVC 2009 - British Machine Vision Conference.
- IBPRIA 2009 - Iberian Conference on Pattern Recognition and Image Analysis.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.
- IROS 2009 - IEEE/RSJ International Conference on Intelligent Robots and Systems.

Luis Montesano

- IEEE Transactions on Robotics.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.
- IROS 2009 - IEEE International Conference on Intelligent Robots and Systems.
- RSS 2009 - Robotics: Science and Systems.
- IJCAI 2009 -International Joint Conference on Artificial Intelligence.

Manuel Lopes

- IEEE Transactions on Robotics.
- International Jornal on Robotics Research.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.
- IROS 2009 - IEEE International Conference on Intelligent Robots and Systems.
- RSS 2008 - Robotics: Science and Systems.
- ICDL 2008 - International Conference on Development and Learning.

Margarida Silveira

- 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
- Autonomous Agents and Multi-Agent Systems (JAAMAS).
- IEEE Transactions on Systems, Man and Cybernetics, part B.

- ICRA 2009 - IEEE International Conference on Robotics and Automation.

Pedro Aguiar

- ELSEVIER Image and Video Computing.

Pedro Lima

- IEEE Transactions on Robotics and Automation.
- Elsevier Journal of Robotics and Autonomous Systems.
- IROS 2009 (Senior PC member).
- 8th International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS'09) (Senior PC member).
- RoboCup Symposium 2009.
- IJCAI09 Workshop on Hybrid Control for Autonomous Systems Integrating Learning, Deliberation, and Reactive Control.
- ICRA 2009.
- Robocomm2009.
- ROBÓTICA 2009.
- 9th Conference on Autonomous Robot Systems and Competitions.

Rodrigo Ventura

- Connection Science.
- AAAI Fall Symposium 2009.
- ACII 2009 - International Conference on Affective Computing & Intelligent Interaction.
- ICRA 2009 - IEEE International Conference on Robotics and Automation.
- EMBC 2009 - IEEE Engineering in Medicine and Biology Conference.
- AAMAS 2010 - International Conference on Autonomous Agents and Multiagent Systems.

2.6.6 Other Activities

Agostinho Rosa

- Evaluation and review expert for “Marie Curie – Life Sciences Program”, IIF, IEF and IOF, October 2009.

António Pascoal

- Member of the panel in charge of evaluating the applications for PhD grants financed by Fundação para a Ciência e a Tecnologia (FCT)

Carlos Silvestre

- Member of scientific evaluation panels of AdI.

Isabel Ribeiro

- Acting as adviser for the Executive Board of FCT (Portuguese Foundation for Science and Technology), was co-responsible for the preparation of the Call for Proposals for Scientific Research and Technological Development Projects in all Scientific Domains launched by FCT. One call opened in November 2008, received around 5800 proposals and during 2009 she was responsible for the IT aspects related with the scientific evaluation. She was responsible for the next call that opened in September 2009, and for the new versions of the “Guide for preparation and submission of R&D projects” and the “Guide for Peer Review of R&D projects”. During 2009 she was the FCT responsible for all the contacts and negotiations with “Programa Operacional Factores de Competitividade”, the funding programme responsible for the allocation of FEDER funds to FCT.

João Paulo Costeira

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

José Santos-Victor

- IST, Vice President for International Affairs**.**

Paulo Oliveira

- Member of scientific evaluation panels of AdI.

Pedro Lima

- Member of the Board of Trustees of the RoboCup Federation.
- Nominated National Delegate to ESA PB-HME (Program Board on Human Activity, Microgravity and Exploration) by the Minister of Science, Technology and Higher Education.
- Nominated National Delegate to EC FP7 Space by the Minister of Science, Technology and Higher Education.
- President elected of the Portuguese Society of Robotics.

2.7 ACADEMIC ACTIVITIES

Here we list the participation, during 2009, 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 Cláudio Miguel Faleiro de Lima, "Substructural Local Search in Discrete Estimation of Distribution Algorithms", University of Algarve, May 2009.

Carlos Silvestre

- Coordinator, Graduate Studies, Scientific Area of Systems, Decision, and Control.

Isabel Ribeiro

- Member of the Aggregation Committee of João Manuel Ferreira Calado, Universidade da Beira Interior, April 2009.
- Member of the jury for the position of Associated Professor for the department of Mathematics of Instituto Superior Técnico, September 2009.
- Member of the jury for the position of Associated Professor for the area of Electrical Engineering, University of Aveiro, April 2009.

João Sanches

- Member of the M.Sc. Thesis Committee: Functional Connectivity Measures in Memory Networks Using Indepenedent Component Analysis, Catarina Saiote Ferreira Leite, - Adviser: Patrícia Figueiredo, MEBM, 25/11/2009.
- Member of the M.Sc. Thesis Committee: Investigation of face processing mechanisms in the brain using fMRI, Joana de Avelar Morgado Ferreira da Silva, - Adviser: Patrícia Figueiredo, MEBM, 25/11/2009.
- Member of the M.Sc. Thesis Committee: Automation of a SMD Component Placement Machine, João Oliveira do Rosário (Tagus) - Adviser: Moisés Simões Piedade e Pedro Girão, MEE, Tagus, 23/11/2009.
- Member of the M.Sc. Thesis Committee: Development of Bioinformatic Tools to Track Cancer Cell Invation using 3D in Vitro Invation Assay, Rui Sérgio Malheiro Caldeira - Orientação: Pedro Quelhas - FEUP, 20/7/2009.
- Member of the M.Sc. Thesis Committee: Categorização de Imagens e Pesquisa de dados através de exemplos, Christophe Rodrigues da Silva - Orientação: Aurélio Campilho - FEUP, 20/7/2009.
- Member of the M.Sc. Thesis Committee: Identificação de regiões nodulares em imagens digitais de radiografia pulmonar, Lúcio Orlando Mourão Alves - Orientação: Ana Mendonça - FEUP, 20/7/2009.
- Member of the M.Sc. Thesis Committee: Adaptive algorithms for wireless channel tracking, Manuel Diogo Santos Mera, Orientador: Gonçalo Tavares (6/4/2009)

João Pedro Gomes

- Member of the Ph.D. Thesis Committee of António João Freitas Gomes da Silva, "Environmental based underwater communications", Instituto Superior Técnico, Lisbon, Portugal, March 2009.

João Sequeira

- Member of the Ph.D. Thesis Committee of Ricardo Vasquez Martin, Universidad de Malaga, Spain, October 2009.

Jorge S. Marques

- Coordinator of the Scientific Area of Systems, Decision and Control, Instituto Superior Técnico, 2009.

José Santos-Victor

- Member of the Ph.D. Thesis Committee of A. Skoglund, “Programming by Demonstration of Robot Manipulators”, Orebro University, June 2009.
- Member of the Ph.D. Thesis Committee of Diego Pardo, "Learning rest-to-rest motor coordination in articulated mobile robots", UPC, Spain, October 2009.
- Member of the M.Sc. Thesis of Ahmed Al-Tunaiji, “2D Binaural Sound Localization”, Khalifa University of Science, Technology & Research (KUSTAR), Abu Dhabi, UAE, June 2009.
- Member of the M.Sc. Thesis of Rasha Abdulrahman Abdulla, “Selective Visual Attention for Urban Search And Rescue (USAR) Systems”, Khalifa Univ. Science, Technology, & Research (KUSTAR), Abu Dhabi, UAE, June 2009.

Luis Montesano

- Member of the Ph.D. Thesis Committee of F. Chersi, Learning through imitation: a biological approach to robotics, supervised by Prof. E. Bicho, Prof. W. Erlhagen and Prof. L. Fogassi, Minho University, Portugal, 2009.

Matthijs Spaan

- Licentiate’s thesis jury member for Per Skoglar, “Planning Methods for Aerial Exploration and Ground Target Tracking”, Linkoping University, October 2009.

Margarida Silveira

- Member of the M.Sc. Thesis Committee of Luis Rosado, “Sistema Automático para diagnóstico de Lesões Cutâneas Baseado em Imagens Dermoscópicas”, Instituto Superior Técnico, Universidade Técnica de Lisboa , October 2009.

Paulo Oliveira

- Member of the Excutive Board of the Department of Electrical Engineering and Computers (IST).

Pedro Lima

- Member of the Ph.D Thesis Committee of Antidio Viguria, University of Seville, September, 2009.
- Deputy Vice-President for Scientific Affairs of IST Scientific Board until July 2009 and then elected member of the new IST Scientific Council.

Rodrigo Ventura

- Member of the M.Sc. Thesis Commitee of Bruno Manuel Ferreira Afonso, “Music Classificaion: An Exhaustive Analysis of Automatic Genre Classification”, Instituto Superior Técnico, Universidade Técnica de Lisboa, November 2009.

Ruben Martinez-Cantin

- Member of the Ph.D. Thesis Committe of Ricardo Vazquez Martin, "OnLine Environment Segmentation based on Spectral Mapping (LESS-Mapping)", Malaga University, October 2009.

2.8 VISITS TO ISR

2.8.1 Distinguished Visitors

- **Prof. Dr. Ronaldo Guimarães Fonseca**, UNESP, Botucatu, SP, Brazil.
- **Thor I. Fossen**, Norwegian University of Science and Technology (NTNU).
- **Morten Breivik**, Norwegian University of Science and Technology (NTNU).
- **Kristin Y. Pettersen**, Norwegian University of Science and Technology (NTNU).
- **Mogens Blanke**, Technical University of Denmark (DTU).
- **Giovanni Indiveri**, University of Lecce, Italy.
- **Pere Ridao**, University of Girona, Spain.
- **John Hauser**, University of Colorado at Boulder, USA.
- **Prof. Fernando De la Torre** – Carnegie Mellon University
- **Prof. Manuela Veloso** – Carnegie Mellon University
- **Prof. Adrien Bartoli** - CNRS laboratory, Clermont-Ferrand, France**.**
- **Prof. Lourdes Agapito** - Dep. of Computer Science, Queen Mary University of London, UK.
- **Prof. Cecilia Laschi**, Scuola Superiore Satnanna, Italy.
- **Prof. Francisco Lacerda**, University of Stockholm.
- **Prof. Alberto Sanfeliu**, Universidad Politecnica de Catalonia.
- **Prof. Fabrizio Smeraldi**, Queen Mary College, University of London.
- **Dr. Jan Peters**, MPI for BiologicalCybernetics, Tübingen, Germany.
- **Dr. Marcel Brass**, University of Ghent, Belgium.
- **Marius Muja,** PhD student from the University of British Columbia, BC, Canada– "Fast Approximate Nearest Neighbors with Automatic Algorithm Configuration", January 2009.

2.9 SPECIAL EVENTS

2.9.1 "From Human Societies to Artificial Societies" (2009 Edition)

Lisbon, Portugal
February 26 – March 26, 2009

Organizers: Dr. Porfírio Silva, Prof. Pedro Lima
Laboratory: Intelligent Systems

Description: Under the Institutional Robotics ISR project, this conference cycle was organized to bring to ISR/IST a set of researchers from different areas of knowledge, so as to shed light over topics more or less closely related to collective robotics, and clarify the different ontologies on related subjects. The conference cycle was open to general audiences and widely advertised in Lisbon and Portugal. This was teh 2nd edition of this cycle, after the one held last year.

WEB: http://institutionalrobotics2009.isr.ist.utl.pt/

PROGRAM:

- 26 February – "Darwinismo Artificial - Evolução Artificial: Arte e Ciência",by Agostinho Rosa (ISR/IST) + "Filhotes de robot? Desenvolvimento pós-natal artificial", by José Santos-Victor (ISR/IST) + "Mundos de significação: no natural e no artificial", Isabel Ferreira (PhD in Linguistics)/commentators: Jorge Carneiro (Instituto Gulbenkian de Ciência), João Sequeira (ISR/IST).

- 11 March – "O Papel da Selecção Natural de Darwin em Heterarquias Biológicas e Sociais", by Luis Rocha (Indiana University) + "Decision-theoretic and game-theoretic approaches to decision making in collectives", by Matthijs Spaan (ISR/IST) + "Emoções, uma ponte entre a natureza e a sociedade?", by Rodrigo Ventura (ISR/IST)/Commentators: Pedro Galvão (Philosophy Center, Lisbon University), Tiago Saraiva (Social Sciences Institute, Lisbon University).

- 26 March – "A Escolha, Apesar da Dificuldade", by Ana Costa (DINÂMIA/ISCTE) + "Vida Institucional Artificial", by Porfírio Silva (ISR/IST) + "Futebol Robótico: A Ciência para Além do Futebol", by Pedro Lima (ISR/IST)/Commentators: José Castro Caldas (Social Studies Center, Coimbra University), Zélia Carvalhais (ISR/IST).

2.9.2 ROBOTCUB Meeting

Lisbon, Portugal
16-17 April 2009

Organizers: Prof. José Santos Victor, Prof. Alexandre Bernardino.
Laboratory: Vislab – Computer and Robot Vision Lab.

Description: The meeting of the RobotCub consortium was held in IST, Lisbon, and consisted of a two-day session with about 50 participants. The meeting included presentations from some of the partners in the consortium and invited speakers. The topics covered humanoid robot design, cognition, sensory-motor coordination, developmental psychology and robotic imitation, among others.

2.9.3 RLSS 2009: Robot Learning Summer School

Lisbon, Portugal
20 – 24 July, 2009

Organizers: Manuel Lopes and Luis Montesano (in cooperation with IEEE Technical Committee in Learning Robots).

Laboratories: Vislab – Computer and Robot Vision Lab
Support: ISR, FCT, EUCogII

Description: During the last years learning robots have increasingly received more attention by the robotics community. There is an increasing interest in machine learning and statistics within the robotics community. At the same time, there has been a growth in the learning community in using robots as motivating applications for new algorithms and formalisms. Considerable evidence of this exists in the use of learning in high-profile competitions such as RoboCup and the DARPA Challenges, and the growing number of research programs funded by governments around the world. Additionally, the volume of research is increasing, as shown by the number of learning papers accepted to IROS and ICRA, and the corresponding number of learning sessions.

This school was mainly designed for PhD students in learning robots who wanted to acquire a good understanding of current research and open challenges. At the same time, it served as a good introduction to those people with a different background who wanted to introduce themselves to this area. The school allowed the participants to get in touch with international experts in this field. More long term results will include exchange of students, joint publications and potential joint projects.

URL: http://vislab.isr.ist.utl.pt/RLSS09/

2.10 Awards and Patents/Prototypes

Awards

Marko Beko

- Prize IBM 2009, awarded July 2009.

Pedro Lima

- Awarded with the Catedra de Excelencia (6 months) by the Board of Governors of the Charles III University of Madrid, Spain.

Pinar Oguz Ekim, João Pedro Gomes, João Xavier, Paulo Oliveira

- Paper at the EUSIPCO'09 conference (ML based sensor network localization and tracking: batch and time-recursive approaches) ranked in the top 5%, invited for journal submission in Elsevier Signal Processing.

Patents/Prototypes

- *"Sistema de Monitor de Temperatura Central para Diagnósticos de Distúrbios do Sono",* João Sanches, Teresa Paiva, Bruno Pereira e Rui Neves, Patente de Invenção Nacional nº 104115.

- *"Metodologa de Registo de Eventos em Diário Electrónico, Implementado em Telemóvel, para Auxílio no Diagnóstico de Distúrbio do Sono"*, Pedro Pires, João Sanches e Teresa Paiva , Patente de Invenção Nacional Nº 104157.

- *"Automated Fetal Measurement from Three-Dimensional Ultrasound Data",* Dorin Comaniciu, Bogdan Georgescu, Sara Good, Gustavo Carneiro and Fernando Amat., US Patent Office 20090093717.

- *"A Method and System for Detection of Deformable Structures in Medical Images"*,Dorin Comaniciu, Shaohua Kevin Zhou, Feng Guo, Jin-Hyeong Park, Gustavo Carneiro, Constantine Simopoulos, Joane Otsuki and John Jackson. US Patent Office 20090010509.

- The ISobotNet is a testbed for Networked Robot Systems developed by ISLab together with VisLab and MRLab, 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 its 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. Ongoing work will extend the number of cameras and the usable indoor space 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.

2.11 PUBLICATIONS

a) M.Sc. Theses (32)

[1] **Bruno Cardeira**, "Architectures for Inertial/GPS Navigation with Application to Autonomous Vehicles", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, March 2009.

[2] **Giovanni Saponaro**, "Object Manipulation from Simplified Visual Cues", Master Thesis in Computer Engineering (Artificial Intelligence Systems), Sapienza University of Rome, Italy, March 2009.

[3] **Henrique de Castro Martins**, "Augmented Reality for the Teleoperation of Robot RAPOSA", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2009.

[4] **Jorge Miguel de Freitas Ferraz**, "Increasing Autonomy For The Robot RAPOSA", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2009.

[5] **André Romão Ribeiro,** "Seguimento de Jogadores num jogo de futebol", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, June 2009.

[6] **Sérgio Daniel Gonçalves Melo Pequito**, "The Entropy Penalized Minimum Energy Estimator", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, July 2009.

[7] **Ricardo S. Cabral,** "Joint Estimation of Correspondence and Motion using Global Rigidity and Local Descriptors", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, July 2009.

[8] **André Ramalho dos Santos Rosado**, "Detecção Automática de Actividade Epileptiforme Interictal no EEG", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, September 2009.

[9] **Dulce Isabel Viegas Calçada**, "Modeling of the Physiology of *D. hansenii* Using Population-based Search Methods for Parameter Estimation", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2009.

[10] **João Pedro de Matos Rodrigues**, "Monitoring Electrocortical Activity during EEG Biofeedback", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, October 2009.

[11] **João Estilita Antunes**, "Hardware Architecture and Fast Deployment Methods for Soccer Robots", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[12] **Hugo Augusto**, "Navegação Autónoma e Percepção Cooperative Entre Robots Aéreos e Terrestres", Hugo Augusto, Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[13] **André Oliveira**, "Software Architecture for Autonomous Vehicles", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[14] **João Picão,** "Development and Sea Tests Validation of an Acoustic USBL Positioning System", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[15] **Ricardo Jorge Baptista Carona**, "Visual Control Of Unicycle Type Robots", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[16] **Sérgio Alexandre Carraça Carvalhosa,** "Cooperative Motion Control of multiple autonomous robotic vehicles: Collision Avoidance in Dynamic Environments", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[17] **João F. P. Crespo,** "A Multidimensional Companding Scheme for Source Coding with a Perceptually Relevant Distortion Measure", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[18] **Bruno Afonso,** "Music Classification - an Exhaustive Analysis of Automatic Genre Classification", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[19] **Fábio Silva,** "Reconhecimento de padrões de Alzheimer em imagens PET", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[20] **Nuno Moutinho**, "Localização e Mapeamento Visual em Simultâneo: Detecção de Zonas de Aterragem", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[21] **Nuno Miguel Pinto Leite**, "Calibração de uma Rede de Câmaras baseada em Odometria Visual", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[22] **Diogo André Pires Vicente**, "Event Detection with Pan-Tilt Cameras", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[23] **Ricardo Jorge Baptista Carona**, "Controlo Visual de Robots Tipo Uniciclo", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[24] **André Falcão**, "Control of Depth of Anaesthesia using Locally Weighted Learning Methods", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[25] **Marco Gonçalo Neves**, "Auto-tuning de Controladores PID pelo método Relay: Optimização de Controlo em Automação Industrial", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, November 2009.

[26] **Hugo Pinto,** "Robotized Microscopy", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

[27] **Diogo Loureiro,** "Web based robotized microscopy", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

[28] **André Baptista,** "Continuous monitorization and automatic detection of cardiac abnormalities with mobile phone", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

[29] **Indira Andrade,** "fMRI Sparse Design for Auditive paradigms: Toward a Signal and Stimulus Perception Improvements", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

[30] **João Raminhos,** "Acquisition of Electrophysiological Signal - Application to a mobile platform from the EOG signal", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

[31] **Arantxa Oquina Barrio**, "Modelling underwater acoustic noise as a tool for coastal management", Erasmus Mundos Master Thesis, Institute for Systems and Robotics, SiPLAB, University of Algarve, 2009.

[32] **Luis Filipe Rosado,** "Sistema para Diagnóstico de Lesões Cutâneas Baseado em Imagens Dermos", Master Thesis, Instituto Superior Técnico, Lisbon, Portugal, 2009.

b) Ph.D. Theses (4)

[33] **António João Silva**, "Environmental-based Underwater Communications", Ph.D. Thesis, Instituto Superior Técnico, Lisbon, Portugal, March 2009.

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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 SYSTEMS Lab (IS)

The ISLab offers the main following facilities:

- 1 all-terrain remotely-operated (by wireless or cable LAN) robot (RAPOSA), endowed with several sensors for detection of dangerous gases, humidity, and temperature, a thermal camera, several web cams (some of them with controllable pan);
- 5 omni-directional (3 wheels) robots endowed with an on-board laptop with wireless communications, rate-gyro, 16 sonars, omni-directional catadioptric system, optical mouse for odometry, electromechanical kicker and rolling drum systems for robotic soccer applications;
- 1 RWI ATRV-Jr mobile robot, 4-wheel drive, equipped with 16 sonars, GPS, inertial navigation module and a compass, pan and tilt vision system and one SICK Laser scanner (shared with the Mobile Robotics and Computer and Robot Vision Labs);
- 1 Blimp aerial robot, with pan and tilt vision system, 3 servomotors, RF link for remote control and remote video-link for video transmission (shared with the Mobile Robotics and Computer and Robot Vision Labs);
- 4 Nomadic Super-Scout II mobile robots, with updated electronics (by IdMind) equipped with 16 sonars and 2 cameras each, one of them part of an omni-directional catadioptric system;
- 14 Philips 740K USB Web Cams, used in the Super-Scout II robots;
- 1 Real-Time RF video link;
- 1 Space Mouse device, for teleoperation of mobile robots and manipulators;
- 35 Pentium Personal Computers (PIII or PIV, including 10 laptops, 4 of them for the omni-directional robots) – under Linux and Windows 2000/XP OS;
- 1 Small humanoid robot (Robotis Bioloid kit);
- 1 Small laser range finder (Hokuyo);
- 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);
- 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);
- 3 quad-core workstations, used for running simulations and other experiments requiring fast

The ISobotNet is a testbed for Networked Robot Systems developed by **ISLab** together with **VisLab** and **MRLab**, 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 its 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. Ongoing work will extend the number of cameras and the usable indoor space 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.

MOBILE ROBOTICS Lab (LRM)

The LRM offers the main following facilities:

- 2 Scout mobile platforms with on-board computer, one of them with a video camera, and wireless Ethernet;
- 1 ATRV Jr Rover with ultrasound sensors, GPS and Inertial Measurement Unit. This mobile platform is shared with the Intelligent Systems and Computer Vision Laboratories;
- 4 Sony dogs Aibo, shared with the Intelligent Systems Lab;
- A complete set of the LEGO Mindstorms system for Mobile Robotics;
- A Laser Range Finder from the Riegl supplier with range and luminance measurement;
- 4 Sick Laser Scanners;
- Three computer controlled Pan & Tilt Units from Direct Perception;
- Video cameras, including two Quick Cams and a Network Eye supporting direct display of real scenes on the Internet;
- 10 Pentium PCs + 5 portable Pentiums;
- Three laser printers, and one DeskJet colour printer;
- 1 PC with VME bus;
- 8 webcams;
- 2 ethernet switches 100Mbps;
- 1 ethernet access point;
- 5 USB wireless adapters;
- 2 pairs of ethernet modems from OTC;
- 1 oscilloscope (digital) Tektronix.

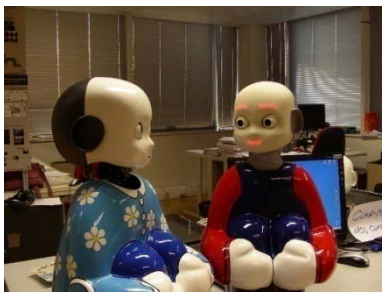
A large open space appropriate for mobile robotics navigation experiments.

COMPUTER VISION Lab (VISLAB)

The VisLab is equipped with various PCs, various cameras (CCD, CMOS, Colour, Black & White, Digital or Analogue) and image frame grabbers, a pan-tilt unit and several pan-tilt cameras.

Special equipment consists of:

- 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. By the summer of 2010, there will be 20 copies of the iCub in different labs around the world, the largest population of conspecific humanoid robots available 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 (see pictures below). This robot was developed at VisLab since 2001 and was one f the most versatile humanoid robots in Portugal.
- Vizzy –humanoid platform mounted on a Segway mobile base. Construction is planned to be finished in 2010. 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.
- Two robotic heads designed for the iCub, each with 6 degrees of freedom, an inertial sensor, audio and ability to perform facial expressions (see pictures below).
- 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


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

DYNAMICAL SYSTEMS AND OCEAN ROBOTICS Lab (DSOR)

Mechanical / Electric shop (8th Floor of ISR) - basic equipment and tools to machine mechanical pieces and to assemble circuit boards.

Very High Precision Callibration Table (for motion sensor testing and calibration)

Small **Zodiac** to support operations at sea.

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.

Autonomous Quadrotor– designed and built by ISR/IST. A quadrotor helicopter with payload capability of about one kg. Was design within the scope of the AIRTICI project for aerial vehicle hardware and software architectures test and evaluation. This prototype will be used in bridge inspection tasks.

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.

Mechanical/ Electrical Equipment

- **Pressure Chamber** - to test the marinization of equipment down to depths of 600 meters.
- **Calibration Equipment** –Ideal Aerosmith, 2103 Series, Multi-Axis Rate Table
- **Crane** with the capacity to handle loads of up to 2500 Kg.
- **Industrial air compressor.**
- **2 Trailers for the transportation of marine vehicles.**

Actuators and Sensors for Robotic Ocean Vehicle Development and Operation (part of the equipment is dedicated to the operation of the autonomous marine vehicles that are property of IST/ISR).

- *Actuators* - 5 electrical thrusters.
- 3 rate gyros, 2 pendulums and 1 fluxgate (Watson's Attitude & Heading Reference Unit AHRS-C303);
- 3 rate gyros, 3 accelerometers and 1 magnetometer (SEATEX MRU-6)
- 3 rate gyros, 2 pendulums and 1 magnetometer (KVH attitude reference unit).
- 1 flowmeter TSA-06-C-A (EG & G Flow Technology);
- 2 depth cells DC 10R-C (Transinstruments);
- 2 echosounders ST200 (Tritech);
- 2 echosounders ST500 (Tritech);
- 1 Sidescan sonar (System Techonologies / Tritech);
- 1 Acoustic Modem for underwater communications (System Techonologies / Tritech);
- GIB (GPS Intelligent Buoys) – GPS based underwater positioning system, with target tracking capabilities.
- 1 Doppler Log TSM 5740 with 4 beams in a Janus configuration, operating at 300 KHz (Thomson-ASM);
- 1 Doppler Log, operating at 600 KHz, rated for 2000 m (RDI);
- 1 set of 3 rate gyros, 2 pendulums and 1 directional gyro from Humphreys.
- 1 *Long Baseline Positioning System* for underwater vehicle positioning - 1 transducer and 4 transponders.
- 1 *DGPS (Differential Global Positioning System)* for accurate surface vehicle navigation - 4 Motorola Encore unit and 3 FREEWAVE radios.
- 1 Multibeam Sonar (Reson Seabat 8125)
- 1 Integrated Sidescan/Subbottom profiler unit (EDGETECH)
- 4 sets of Acoustic Modems

Software Tools for Navigation, Guidance, and Control System Design.

NetMarSys (Networked Marine Systems Simulator), with Hardware-in-the-loop capabilities. Modeling and simulation tool for *the integrated analysis and design of navigation, guidance and control systems for multiple autonomous marine vehicles.* The software was developed at IST/ISR and is built around the commercially

available package MATLAB. It provides the means to assess the combined performance of navigation, guidance, and single and multiple vehicle control systems prior to their implementation.

General Computer Facilities.

a. 12 Desktop PCs
b. 8 Laptop PCs
c. 2 Laser printers

EVOLUTIONARY SYSTEMS AND BIOMEDICAL ENGINEERING Lab (LASEEB)

The Laseeb offers the main following facilities on digital signal processing for biomedical engineering, digitalization and development for multimedia applications:

- 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.