

Applying Cognitive Processes to Robotics (TIN 2006-14939)

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Abstract

The main aim of this project is the use of cognitive processes to provide intelligent behaviour to robots, so that they can: reason about what they are identifying while they are navigating, build maps where the most relevant information is included, learn in an intuitive way as human beings do, get useful information from the high amount of data obtained from sensors and to interpret them emotionally, among other things. This report summarizes the most relevant results of our project and discusses the relevance and usefulness of them regarding scientific contribution, technology transfer, personnel training and collaborations with other groups.

Keywords: Cognitive Reasoning, Cognitive Vision, Robotics.

1 Main Objectives

This project is a continuation of two previous CICYT projects, where theoretical qualitative models for representing and reasoning with spatio-temporal aspects such as orientation, topology, shape of objects, distance, velocity and acceleration were developed. Moreover, in those previous projects, the preliminary results in the application of these models to simulated and real robot navigation were also obtained. In particular we solved two practical problems: the automatic and intelligent assembly of ceramic mosaics by recognising tesseraes from pictures against a vectorial mosaic design; and the almost-SLAM problem, one of the challenges for the Aibo robots at the Robocup championship.

Our research interest in this project is still the use of cognitive processes to provide intelligent behaviour to robots: to allow the robots to reason about what they are finding while they are navigating, to build maps where the most relevant information is included, to learn in an intuitive way as human beings do, to get useful information from the big amount of measures obtained from sensors, and to interpret them emotionally, among other things. In particular, in this project we will work on the following aspects:

- 1) Sensor integration of distance sensors and visual images.
- 2) Sensor emotional interpretation.
- 3) Automatic maps construction of the robot environments with hybrid (qualitative + quantitative) representation and reasoning. We will use the maps for path planning and localization.
- 4) The integration of reasoning models about orientation, distance, velocity, acceleration and trajectories to the navigation process of real mobile robots.
- 5) The definition of a new qualitative model about trajectories of objects.

- 6) The definition of new methods for cognitive vision.
- 7) The development of new cognitive/qualitative learning techniques, by a qualitative treatment of quantitative learning techniques, or by the development of new methods based on the latest scientific results in the neuroscience field.

In order to afford our objectives, we have defined the following tasks:

1. **Sensor data integration:** Integration of data provided by robot sensors at a qualitative level, enabling the robot to perform a decision-making in a more efficient and robust way, despite the inaccuracy, incompleteness and inconsistency in the data obtained by these sensors.
2. **Map Building:** Automatic hybrid (qualitative-quantitative) maps building, including reasoning processes.
3. **Integrating qualitative reasoning models for robot navigation.**
4. **Development of a hybrid model (qualitative-quantitative) to represent and reason about trajectories.**
5. **Cognitive vision.**
6. **Qualitative learning:** Development of new qualitative methods for learning by implementing models based on current scientific discoveries in the field of neuroscience.
7. **Sensor data integration based in emotions.**
8. **Automatic assembly of tile mosaics.**
9. **Automatic sweeping of any flat surface.**
10. **Obstacle detection.**
11. **Obstacle avoidance.**
12. **Navigation in 3-dimensions:** Application of our qualitative model for representation and reasoning in 3-dimensions to the navigation of the hexapod robot Lauron IV.

2 Level of Success

The project outcome has been satisfactory over its first two years of development. This section is aimed to describe the results obtained till now regarding the project objectives, together with the publications generated from them. It is important to point out that due to the fact that we have asked for 2 patents, it has not been possible to publish most of the results before presenting them. As we have already the patents presented we are now preparing publications for journals.

TASK 1. Sensor data integration (90% fulfilled): [1, 2, 3, 4, 5, 6, 7]

We have implemented the theoretical model developed previously in our group on real robotic platforms. We are currently working on the integration of range sensors with visual images.

TASK 2. Map Building(75% fulfilled): [8, 9, 10, 32],

We have implemented the automatic building of hybrid (qualitative-quantitative) maps, including representation and reasoning processes about orientation. Maps are being used for self-localization and the automatic scanning of surfaces. We are now verifying the proper operation and robustness to different environments. These maps have already been tested with the real robot Pioneer 2 and now we are also developing software embedded components where cognitive processes will serve to provide intelligent and autonomous behaviours to service robots (industrial and domestic vacuum cleaners). We have presented the patent entitled “**Método de Construcción**

Automática de Mapas Integrando un Proceso de Razonamiento Cualitativo” with data February 4, 2008.

TASK 3. Integration of qualitative reasoning models to robot navigation processes (50% fulfilled): [8]

We are integrating qualitative reasoning models regarding named distances and velocity to the navigating and map building processes of a mobile autonomous robot. We have tested our integration in Pioneer and Aibo robots. This result is part of the patent named in the previous task.

TASK 4. Development of a hybrid model (qualitative-quantitative) to represent and reason about trajectories(75% fulfilled): [11, 12, 13]

A complete qualitative model for representing and reasoning about trajectories regarding any kind of moving objects has been developed. This model has been tested by using a simulator and an Aibo robot. We have **asked for the study of the technique** (*estudio de la técnica*) in order to know if the model is patentable and we have obtained a **positive answer**. We have started to write this patent, titled **“Tecnología para la Representación y el Razonamiento Cualitativos de Trayectorias de Objetos por parte de un Robot”**.

TASK 5. Cognitive vision(90% fulfilled): [14, 15, 16, 17, 18, 19, 20]

A model for qualitative shape description and recognition has been developed. This model has been tested in an industrial vision system for the assembling of tile mosaics (task 8).

Moreover, another model for qualitative image description has been developed and tested with real images. This model integrates qualitative models of shape, orientation, topology, distance, etc.

TASK 6. Qualitative learning(starting now):

The main researcher of this project is now studying this subject while she is doing a research stay at the University of Washington (Seattle, USA).

TASK 7. Sensor data interpretation based on emotions(20% fulfilled): [21]

An expert system to assign and analyse emotions of Aibo robots while playing football, depending on the roles they have (fellow team member or opponent), has been implemented.

TASK 8. Automatic assembling of tile mosaics(80% fulfilled): [22, 23, 24, 25, 26, 34]

Software regarding the automatic assembling of tile mosaics has been developed. This work is Lledó Museros’ **thesis** and was awarded in 2007 with the **Premio del Consejo Social de La Universidad Jaume I**, and as a consequence, a **book** was published [25]. This software was tested in an ABB manipulator robot with 6 degrees of freedom and now we are adapting it in order to test it by using our new Mitsubishi PA-10 robot which we bought with FEDER funds.

TASK 9. Automatic sweeping of any flat surface(70% fulfilled): [27]

We have developed software for automatic sweeping of any flat surface and we have tested it in our Pioneer robots obtaining successful results.

Moreover, thanks to our FEDER funds, we have bought two industrial scrubbing machines and a lawnmower, we have added the needed sensors and actuators to make them autonomous robots and we have also built a prototype of an autonomous domestic vacuum cleaner. Now, we are adapting the software developed for the Pioneer robots to apply it to all these machines.

TASK 10 and 11. Obstacle detection and avoidance(90% fulfilled): [33, 35]

An Application Programming Interface (API) has been developed in order to transfer all the programmes regarding obstacle detection and avoidance, most of them available in Webots simulator, to the real Aibo robots. Moreover, our group developed a vision controller (not available

in Webots simulator) which connects the camera of the simulated Aibo robot in Webots to the real camera in the real Aibo.

TASK 12. Navegación en 3-dimensiones(20% fulfilled): [28, 29, 30, 31]

We are modelling the hexapod robot LAURON IV in Webots simulator and developing the cross-controllers in order to programme it.

3 Results

In our opinion, the *degree of accomplishment of the objectives of our project* is satisfactory. In this section, we first present the indicators of our *scientific production*. Then, we explain the *transference of our results to technology*. The next section describes our achievements in *research training* and the last section explains our *collaboration with other research teams*.

3.1 Scientific Production

In section 2, we have already related our publications to the tasks carried out in this project. In this section, we summarize our scientific production in Table 1, which classifies the number of published works with respect to the kind of publication and shows the references which describe them. Some **journal articles** dealing with the research work regarding: (1) the accepted patent and (2) the finished thesis; are in process of writing at the moment.

Kind of Publication	Total	References
Thesis	1	[24]
Books	1	[25]
Book Chapters	5	[2], [4], [9], [13], [16],
International Conference Papers	6	[15], [17], [18], [19], [23], [27],
National Conference Papers	9	[3], [5], [6], [7], [11], [12], [14], [20], [22],
Reports	12	[1], [10], [21], [26], [28], [29], [30], [31], [32], [33], [34], [35].

Table 1. Publications related to our project.

3.2 Technology Transfer

Some members of this research group have created the company “**Cognitive Robots SL**”. Cognitive Robots is a spin-off from the University Jaume I, located in the Technological Park. The company was constituted to apply the research results obtained by the Cognition for Robotics Research group (C4R2) at UJI and exploit them. Cognitive Robots main activities are: the development of software embedded components where cognitive processes will serve to provide intelligent and autonomous behaviours to service robots (industrial and domestic vacuum cleaners; trolley for hospitals, airports, supermarkets, etc.) and any other cognitive component (such as systems for automatic collision avoidance, etc.).

We have presented the patent entitled “**Método de Construcción Automática de Mapas Integrando un Proceso de Razonamiento Cualitativo**”, with number P200800289, filed by the

UJI February 4, 2008, at the Spanish Patent and Trademark Office (O.E.P.M.). We are now waiting for the resolution of the **Patent Cooperation Treaty** process (PTC).

3.3 Researcher Training

A total number of 10 people have been involved in the project. From them, only 4 people are full time working in the U. Jaume I or U. of Valencia as follows: Dra. Ll. Museros with an *Ayudante Doctor* position, Dra. M. T. Escrig and Dr. S. Moreno with *Titular Universitario* positions and Z. Falomir who holds a pre-doctoral grant supported by the Generalitat Valenciana. The rest of the members of the team have *Profesor Asociado* positions and during some months of the project there has been **2 researchers** (J. Grande and V. Castelló) **supported by the project**.

Dr. Ll. Museros's **PhD dissertation**, advised by Dr. M.T. Escrig and Dr. C. Freksa, was presented in December 2006. It is entitled "Qualitative Theories On Shape Representation And Movement. Application To Industrial Manufacturing And Robotics" [24], and it focus on the fourth and sixth project objectives. Part of the work developed in this PhD has been awarded during 2007 with the award "**Premio del Consejo Social de la Universidad Jaume I**". Dra. Museros has hold the mention of European PhD. Moreover, Ms. Z. Falomir and Mr. Juan Carlos Peris have presented their **DEA (Diploma de Estudios Avanzados)** during the project life and, during this year, they plan to finish their PhD on "Sensor Information Integration and Qualitative Image Description", related to the first and fifth objectives of the project, and "Application of Qualitative Representation and Reasoning Models for Robotics: A Cognitive Approach to the Problem of SLAM", related to the second and third objectives of the project.

Finally, Dr. Ll. Museros has reached the *Profesor Contratador Doctor* accreditation and nowadays she is preparing the public competition which will take place during this year.

3.4 Collaboration with other Teams

During the execution of this project we have worked with the **University of Valencia**, some of whose members are included in this project (Dr. Salvador Moreno and David Graullera). As a result of this collaboration we have published several works [6, 7, 9, 15, 16, 27]. Also, in task 4, we have worked with the **University of Valladolid**, located in Segovia (with Professor José Vicente Alvarez-Bravo, Jose Juan Alvarez-Sanchez and Jose Francisco Gonzalez-Cabrera), resulting in several publications [11, 12, 13]. The most important result of this latest collaboration is the pending patent "**Tecnología para la Representación y Razonamiento Cualitativos de Trayectorias de Objetos por Parte de un Robot**".

We presented the work of this project in the **VII Framework Programme**, which was not finally funded, with the name "Cogni-Robot: A cognitive robot for assistance and personal companion". During the process of preparation, this group collaborated with the following consortium:

1	University Jaume I (Coordinator)	UJI	Spain
2	University of Valencia	UV	Spain
3	Investigación y Desarrollo Informático, EIKON, S.L	IDI	Spain
4	Mecanismos Técnicos y de Laboratorio, S.L.	MTL	Spain
5	Cognitive Robots, S.L.	C-ROBOTS	Spain
6	Essence Vision, S.L.	Essence	Spain

7	Instituto Tecnológico del Hábitad	INTHAB	Spain
8	Smart Homes, S.L.	SH	Netherlands
9	Robosoft, S.L	Robosoft	France
10	Technische Universität München	TUM	Germany
11	West University of Applied Sciences	HESSO.HEIG-VD	Switzerland

Moreover, Dra. Ll. Museros has signed **3 research contracts**, based on Article 83 of the LOU, with the **“Instituto de Tecnología Cerámica” in Castellón**, working on the introduction of cognitive processes in the ceramic manufacturing processes.

Zoe Falomir has made a stay of 3 months (from September to December 2008) at the **University of Bremen (Germany)** collaborating with the **Cognitive Systems group (Cosy)** led by Prof. Christian Freksa. During her stay, she has begun to develop a model for obtaining an index of similarity between images described qualitatively. In the near future is expected to make more visits to the University of Bremen.

As a result of contacts made from this project, Dra. M. Teresa Escrig is currently undertaking a sabbatical at the **University of Washington (Seattle, USA)**, with the group **Robotics and State Estimation Lab** led by Dr. Dieter Fox.

Finally, as a result of the studies of the task of Cognitive Vision, we have established closer contact with the group **"IDINFOR (Research, Development and Innovation in Computer Science)"** from the **University of Seville**, directed by Juan Antonio Ortega, which has resulting in the request for two stays at the university by two members of the group (Zoe Falomir and Lledó Museros) that are awaiting resolution. These stays are planned for this summer, before the completion of the project.

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