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Laboratoire Franco-Mexicain d´Informatique
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1. Project Title : A Natural Language Interface for Robot Command and Control

Keywords (4 maximum) : **human language technology ; autonomous robots ;**

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5. Description détaillée du projet:

5.1 Research Background:

Subject : Real-time human-robot interaction for goal directed behavior

As robots become increasingly capable of complex sensory and motor functions, with the ability to carry out increasingly complex tasks, the ability to interact with them in an ergonomic, real-time and adaptive manner becomes an increasingly pressing concern. The current project seeks to combine state of the art autonomous robot control with state of the art cognitive systems for language based interaction in order to provide a robust language-based human-robot interface.

Ideally, research in Human-Robot Interaction will allow natural, ergonomic, and optimal communication and cooperation between humans and robotic systems. In order to make progress in this direction, we have identified two major requirements: First, we must study a real robotics environment in which technologists and researchers have already developed an extensive experience and set of needs with respect to HRI. Second, we must study a domain independant language processing system that has psychological validity, and that can be mapped onto arbitrary domains. In response to the first requirement regarding the robotic context, we will study the Robot Command and Control in the international context of robot soccer playing, in which the Mexican group competes at the international level. From the psychologically valid language context, we will study a model of language and meaning correspondence developed by the French laboratory that has described both neurological and behavioral aspects of human language, and has been deployed in robotic contexts.

State of the Art :

A. Robot command and Control in the Aibo Robocup Domain

RoboCup [3] (originally called Robot World Cup Initiative) is an international research and education initiative providing unified soccer problem domain for intelligent robotics. In such a dynamic environment, multiple fast-moving robots must collaborate in achieving their goal-scoring objective under different group strategies. There are multiple leagues in RoboCup each with its own challenges such as global versus local vision, wheel versus legs, hardware versus software, simulated versus real time, etc. The common denominator among these leagues is that of robot autonomy.

Sony AIBO League [1] is of particular interest to our project since it is the only league where no hardware construction is required. The AIBO league uses a standardized software platform, Open R [2], where teams must develop their own software algorithms based on a unique hardware architecture. Each team consists of our four four-legged robots, where each robot incorporates its own processor, leg and head articulations, video camera and sensors that allow it to interact with the outside world. There exist a number of challenges that need to be solved in order for AIBOs to play soccer. First, the robot must be able to process real-time images in order to identify objects in the soccer field (players, goal, ball, etc.). Additionally, the robot must be able to know its location in the field, must be able to walk with its four legs and perform specialized actions such as kick the ball towards the goal and block incoming shots in the case of a goalie. The robot must be able to take decisions about what actions (behaviors) and when they should be taken, while sharing this information with the other robots in developing a team strategy.

The AIBO league presents a number of interesting challenges for autonomous and collaborating robots:

- **Perception.** Visual object recognition depends on both internal and external robot considerations. In particular, external conditions such as lighting and color calibration critically affect overall robot performance. For example, under poor lighting conditions, some colors may be confused with others, causing the robot to perceive erroneous information, thus affecting localization. On the other hand, different tones of similar colors can also confuse the robots perception systems. While more complex recognition algorithms could solve these problems, such an approach will directly affect processing efficiency.

- **Motion.** Four-legged robot walking requires coordinated joint movement. Quick movements have a direct effect on game performance. On the other hands, perceptions and motion need to be synchronized in achieving optimal results.
- **Coordination.** Team playing has an important effect on game results. While robots need to be individually efficient, coordination between robots is key to successful game performance against advanced teams. Coordination in the form of strategies varies depending on individual robot abilities, number of players at a particular moment in a game, etc. It is crucial to be able to experiment with different strategies and evaluate their performance against different teams and game conditions.
- **World model.** Taking advantage of wireless communication between robots, it is possible to build a unique shared model of the field, ball and robot location. Such a model reduces the uncertainty in robot localization and enriches the coordination strategies between robots. By perceiving the ball, a far away robot may inform better-positioned team members to reorient and move towards the ball.
- **Action recognition.** There are many areas of improvement in current AIBO game strategies. For example, most teams do not pay any attention to action recognition as opposed to more traditional object recognition. In action recognition, robots may be able to anticipate opposite team actions by recognizing game situations, such as kicking the ball or blocking a team member.

The following are the more common AIBO strategies used by teams : (i) individual behavior without collaboration, (ii) collaboration with static roles, and (iii) collaboration with dynamic roles.

Individual Behavior

A classic individual behavior strategy used by several teams [6] is to have two types of players, a goalkeeper and an attacker. In Figure 1 we shows a sample state transition for a goalkeeper.

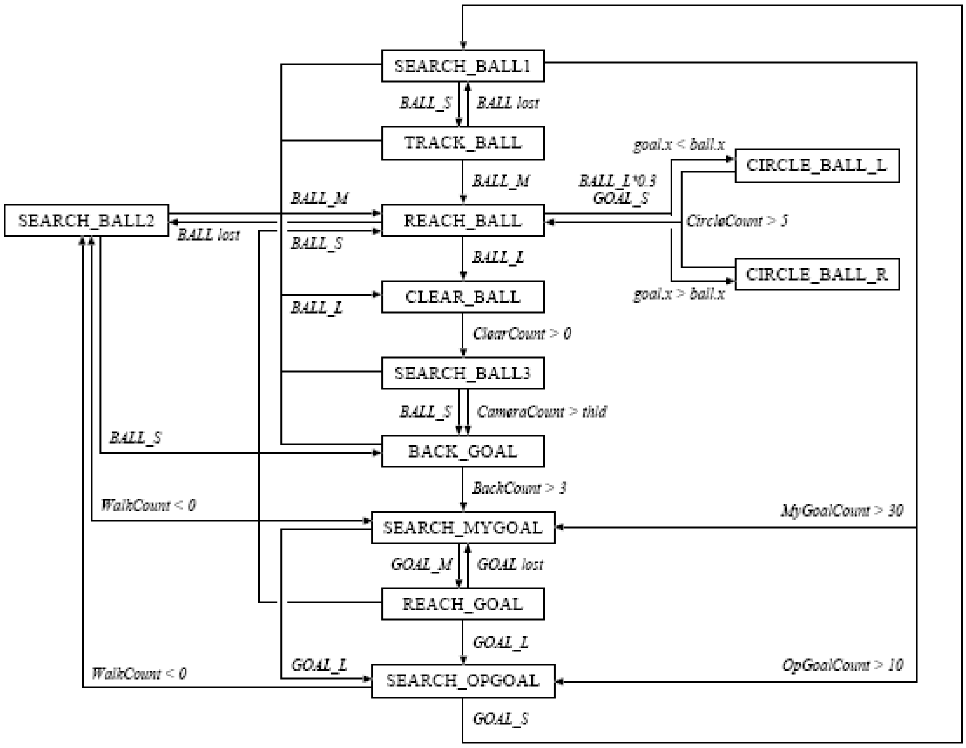

Figure 1. Goalkeeper state transition

The attacker strategy usually involves searching for the ball by circling around the field. When finding the ball, the robot will approach and stop in front of it looking around to check its orientation in order to shoot the ball in the right direction. Self-localization is important both for correct orientation as well as in avoiding the illegal defender rule where no player besides the goalkeeper can be present in the defending area.

Collaboration with Static Roles

Another kind of strategy is to assign static roles to players. For example, in [7] robots have three separate roles: primary attacker, offensive supporter, and defensive supporter. In this model, each robot role requires a different agent to negotiate with other agents the plays to be made. To achieve this model a global world model is usually built, where robots share information among themselves. Information shared includes current robot position and an uncertainty estimate for that position; estimation of the ball's position and the uncertainty associated with it.

The field players have their role assigned in a fixed manner as: primary attacker, offensive supporter, and defensive supporter, respectively. The primary attacker is specified first, followed by the defensive supporter, and finally the offensive supporter. This order is designed to make the system more robust. If one or two of the robots fail, the remaining members of the team can carry on playing.

Collaboration with Dynamic Roles

In order for robot to collaborate while having dynamic roles, a common approach is the use of a decision tree combining information from visual input and the existing world model to define the next set of actions to be performed. The tree is generally split into three levels, corresponding to strategies, roles and skills [5,6], as shown in figure 2. The top most level defines strategies that can be used. For example, one strategy could have the robots spread out passing the ball around. Another strategy could make the robots play as attackers, and another could have all robots play defensively. At this level different strategies can be developed and tested against each other. During a game, robots may be programmed to switch strategies depending on the current score, or how much time it is left in the game.

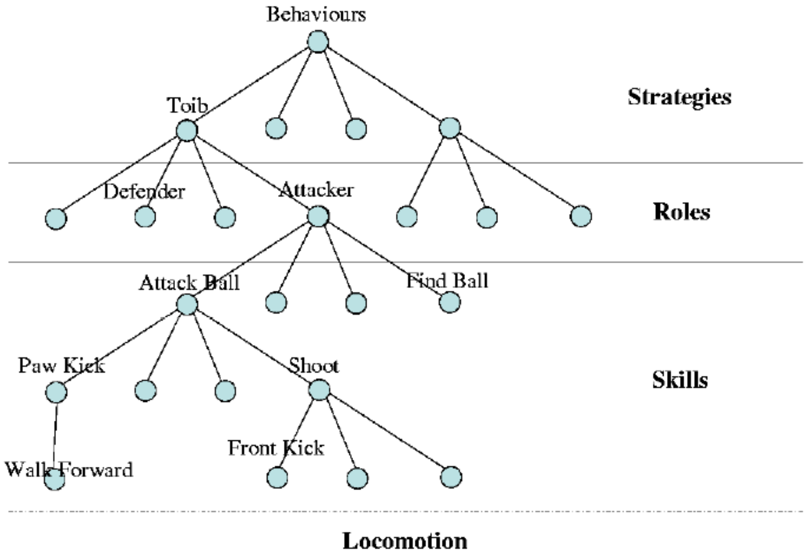

Figure 2. Decision tree for robot collaboration with dynamic roles

Each strategy incorporates a number of roles that robots can be performing. Examples include attackers, supporters and defenders. These strategies are in general dynamically switched during a game, except for the goalkeeper role fixed to a particular robot. At the bottom level each robot contains a number of skills.

<u>State of the Art B. Human Robot Interaction:</u>

Largely based on recent developments in speech technology, robotics, and computing power, Human – Robot interaction has become a rapidly developing and important research domain. This is revealed by the existence since 1997 of the International Conference on Intelligent User Interfaces, and the inclusion of Human Interaction in the IEEE-RAS/RSJ International Conference on Humanoid Robots, initiated in 2000. Research in this domain has revealed that four crucial aspects must be addressed in a successful human-robot interaction context. First, the behavioral environment must be well defined, and rich enough to benefit from such interaction. The Aibo RoboCup environment described above clearly meets these requirements. Second, the use of extra-linguistic media, including vision, must be clearly characterized. Third, the system must use an appropriate language model for mapping back and forth from sentences to meaning, and finally, all of this must be embedded in a robust software engineering context for building reliable human language technology systems.

Visual Event Processing : One of this principal problems in computer vision has been to develop robust algorithms for interpreting scenes and events, once object identification and tracking have been achieved. Exploiting the idea that perceptual primitives can provide the basis for this robustness, Siskind [15] has demonstrated that force dynamic primitives of contact, support, attachment can be extracted from video event sequences and used to recognize events including pick-up, put-down, and stack based on their characterization in an event logic. Related results have been achieved by Steels and Baillie [16]. The use of these intermediate representations renders the system robust to variability in motion and view parameters. Most importantly, this research demonstrated that the lexical semantics for a number of verbs could be established by automatic image processing.

We have recently exploited this approach, using the perceptual primitive of contact to categorize physical events, as depicted in Figure 3 [19].

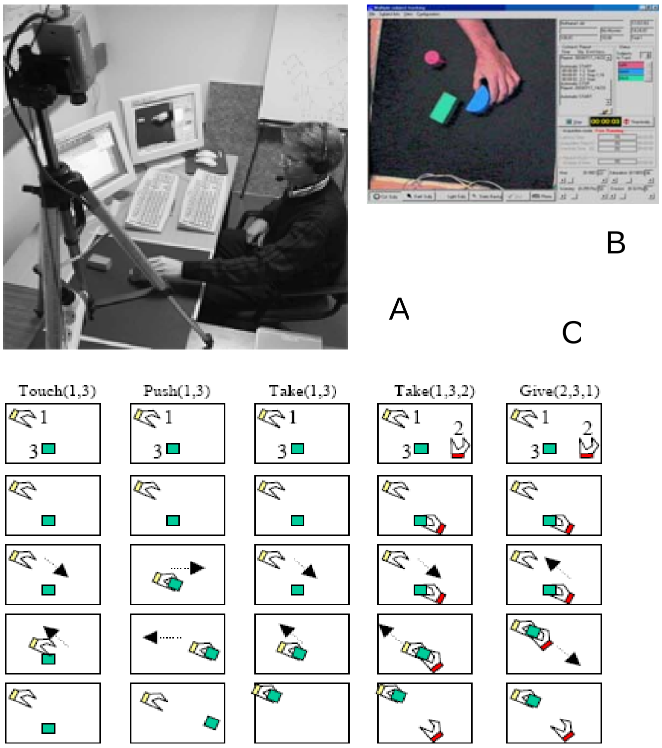

Figure 3.
A. Human-Robot Interaction System overview Human operator performs events with blocks, describes them to the robot for learning, and then asks the robot questions about the events during demonstration of learning.
B. Snapshot of visual input to robot.
C. Temporal template of contact events that allow the vision system to recognize touch, push, take and give events.

Human Language Technology and Language Modeling:

Human Language Technology refers to systems for speech recognition and conversion to text, speech synthesis and dialog flow of control. These issues have been the subject of extensive funding from the DARPA (Defense Advanced Research Projects Agency), and have resulted in the development of public domain HLT toolkits including the CMU Communicator [17], and the related CSLU Toolkit [18]. We have used the CSLU Rapid Application Development (RAD) toolkit as described below.

A crucial issue in human-robot interfaces is the manner in which meaning is exchanged via natural language. In this context, different classical methods are available including context free grammars and n-gram models, and these grammars can be directly exploited in available software packages including the CSLU Toolkit, and the CPK-NLP Suite. In this context, we have developed a language model based on the construction grammar theory, that has the advantage over many other approaches that it can learn to accommodate new grammatical structures through training. We have demonstrated the utility of the construction grammar approach in a human-robot interaction platform.

Figure 3 illustrates the set-up of our human-robot interaction platform. This platform was initially used to generate <Sentence, Meaning> pairs for training the grammatical construction model illustrated in Figure 4. Sentences are extracted from spoken speech using commercial speech to text capabilities, and meanings are extracted from video images of events based on "parsing" of the temporal sequence of contacts, outlined in Figure 3C. Once the model has been trained, the learned grammatical constructions can be used by the model to generate the corresponding sentence for a given meaning. This has been exploited in a scene description and question-answer system (Dominey et al. 2004) [19].

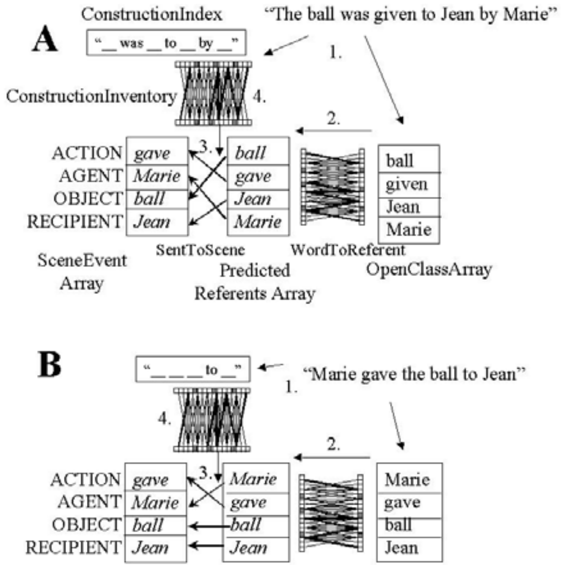

Figure 4. Grammatical construction architecture. Processing of active and passive sentence types in A, B, respectively. On input, Open class words populate the Open Class Array (OCA), and closed class words populate the Construction index. Visual Scene Analysis populates the Scene Event Array (SEA) with the extracted meaning as scene elements. Words in OCA are translated to Predicted Referents via the WordToReferent mapping to populate the Predicted Referents Array (PRA). PRA elements are mapped onto their roles in the Scene Event Array (SEA) by the SentenceToScene mapping, specific to each sentence type. This mapping is retrieved from Construction Inventory, via the ConstructionIndex that encodes the closed class words that characterize each sentence type.

5.2 Research Objectives :

Given this background, the principal objective of the project is to develop a robust and reliable human robot interface based on natural language. The interface is to be between Aibo Robots in the RoboCup context, and coaches that direct the activity of the robots. The RoboCup environment has been chosen because it is a well documented standardized robot environment that the ITAM team has extensive experience with, and thus provides a quantitative domain for evaluation of success. This objective is consistent with the major axes of the call for proposals with respect to agent based distributed systems, image processing, robotics and communication.

While the communication should be relatively free, it shall be organized around the structure of the task, i.e. the RoboCup domain. Indeed, a sub-objective is to demonstrate that the predicate(argument) representation of the meaning of natural language utterances can generalize to different domains, including the Robocop task. Thus, in this task, the human – robot interactions can be broken down into four categories:

1. Game commands: Specific instructions about what to do – including *Shoot, Pas the ball to X, Defend the goal.*
2. State interrogations: Questions including - what are you dining, where are you, how far are you from the ball, etc.
3. Justification interrogations: Principally concerned with determining why the robot performed a given action.
4. Coaching strategy: Transmission of strategy knowledge, e.g. "If you are blocked in front, pass the ball to one of our players behind you."

For each of these interactions we will establish the mapping between language and meaning (in the context of robot control), with these mappings represented as communicative constructions that can be used in a generalized manner. Thus, game commands will involve communicative constructions that transform commands such as "Pass the ball to John" into robot command syntax of the form "pass(ball, John)". State interrogations and justification interrogations will be transformed into queries that interrogate system control data structures. The response to these queries will then be transformed into a human understandable sentence that will be played by the speech synthesizer. Coaching strategy interactions will modify a database of rules that define behavior such as "if possess(ball) and goal(blocked) then pass(ball)".

5.3 Methodology :

5.3.1 Define Communicative Constructions for different interaction types

This will involve for each command types above, a mapping from the grammatical structure of the command onto the predicate(argument) structure of the Aibo level command.

Samples of these instructions from coach to attackers:

a. To one attacker:

1. *Shoot.* When a player has the ball, the coach can order that player to kick the ball. This action can be used to kick the ball towards the opposite team goal or to kick it away from its own goal.
2. *Pass the ball.* When a different attacker to the one near the ball has a better position to take a shot, the coach can order the attacker close to the ball to pass the ball to the other attacker.
3. *Defend a free kick.* Currently, the game is not stopped for a free kick, however this rule can change in the future. In that case, the coach can order a robot to go defend a free kick in order to avoid a direct shot to the goal from an opposite player.

b. To multiple attackers:

1. *Attackers defend.* When an attacker loses the ball the team may be more vulnerable to an opposite team counterattack. The coach can order the attackers to go back to the goal and defend it.

Sample instructions from coach to goalie:

1. *Goalie advance.* In some occasions the goalie will not go out to catch the ball, due to the ball being out of range. There are some situations when the opposite would be desired, for example, to avoid a shot from an opposite attacker. The coach can order to the goalie to go out and catch the ball.

Sample instructions from coach to defender:

1. *Retain the ball.* There are some occasions when we may want a player to retain the ball. This action can be used when other players are retired from the field. The coach can order a defender to retain the ball.

2. *Pass the ball.* Similar to attacker *pass the ball.*

Sample instructions from coach to any player:

1. *Stop.* Stop all actions in order to avoid a foul to avoid obstructing a shot from its own team.
2. *Localize.* When the coach sees that a player is lost in the field, he can order the player to localize itself again in the field.

Sample instructions from coach to all players:

1. *Defend.* Defend with all players. Everybody move a defensive position.
2. *Attack.* Attack with all players (except goalie). Everybody move an attacking position.

Sample queries from coach to any player:

1. *Your action.* The player returns the action that it is currently taking.
2. *Your localization.* The player returns its localization in the field.
3. *Your distance to the ball.* The player returns the distance to the ball.
4. *Objects that you can see.* The player returns all the objects that it sees (landmarks, players, goal and ball).
5. *Why did you do that action?* The player returns the reasons for a particular action taken. (For example, the player was near the ball and saw the goal, so the player kicks the ball to the goal.)
6. *Your current behavior.* The player returns its current behavior (attacking, defending, etc)

For each of the interaction types described above, we will define the communicative construction that identifies the structural mapping between grammatical sentences and commands in the robot interaction protocol.

5.3.2 Define the dialog model and interaction protocol

Once the command level interface is defines, it must be inserted into the general "back and forth" exchange structure of the Human-Robot dialog. Concretely, below are two sample dialogs between coach and attacker, and coach and goalie.

Sample 1. Coach instructing an attacker.	Sample 2. Coach instructing the goalie.
Coach: Do you see the ball? **AIBO:** No, I don't. **Coach:** The ball is behind you. Turn 180 degrees. **AIBO:** Ok. **Coach:** What objects do you see? **AIBO:** I only see the ball. **Coach:** What is your distance to the ball? **AIBO:** 30 centimeters. **Coach:** Go to the ball **AIBO:** Ok. **Coach:** Now pass the ball to the AIBO 2. **AIBO:** What is the position of the AIBO 2? **Coach:** The position of the AIBO 2 is x,y. **AIBO:** Ok. **Coach:** What is your current action? **AIBO:** I'm turning right 40 degrees. **AIBO:** Now I'm passing the ball to the AIBO 2. **Coach:** Ok, Now go back to your goal. **AIBO:** Ok.	**Coach:** Do you see the ball? **AIBO:** Yes. **Coach:** What is the distance to the ball? **AIBO:** More than 60 centimeters. **Coach:** Be careful. The opposite team have the ball. **AIBO:** Ok. **Coach:** If you see the ball in a distance less than 40 centimeters, go out for catching the ball. **AIBO:** Ok. **Coach:** What is your current action? **AIBO:** I'm going out in order to catch the ball. **Coach:** Why did you do that action? **AIBO:** I saw the ball 30 centimeters away from my position, so I follow your order. **Coach:** Ok.

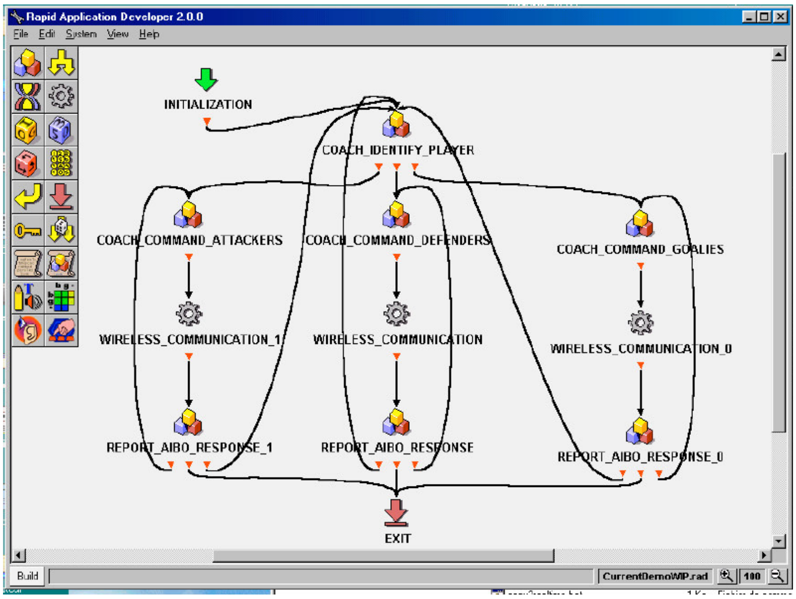

Figure 5. Prototype dialog model for COACH-Aibo interactions. In order to constrain the speech recogntion, the coach will first identify the player(s) he is speaking to, and will then enter into a domain specific COMMAND interaction. Commands will be transmitted to the Aibo by wireless communication, the Aibo will performrespond and any message will be spoken to the coach by a synthesizer. The coach can then choose to continue to interact with the same players (as in Sample 1), or shift to a new player (as in the trasnition from Sample 1 to Sample 2).

5.3.3 Allocate these functions to software and hardware:

System Architecture. The AIBO soccer playing system includes specialized perception and control algorithms with linkage to the Open R operating system. Open R offers a set of modular interfaces to access different hardware components in the AIBO. The teams are responsible for the application level programming, including the design of a system architecture controlling perception and motion. In Figure 6 we show a typical AIBO system architecture. The architecture includes the following modules:

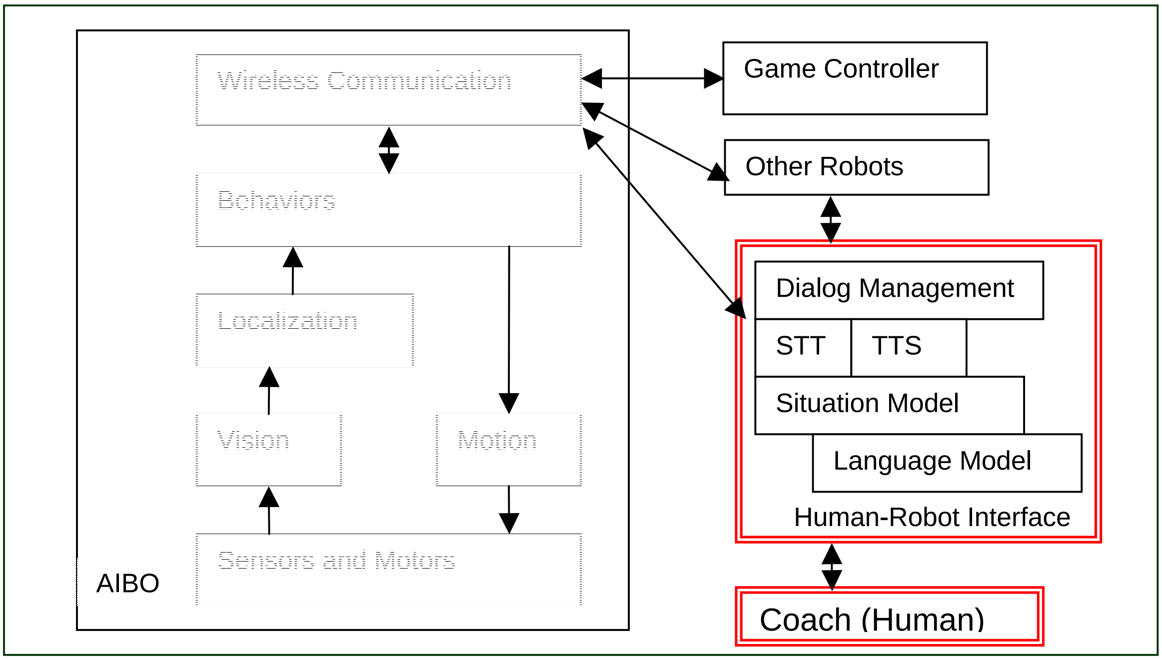

Figure 6. AIBO robot system architecture. Modules are developed by each team with access to hardware via Open R system calls. Subsystems "Coach" and "Human-Robot Interface" correspond to new components for the human-robot interaction. This includes the Dialog Manager (implemented in CSLU RAD), the Speech to Text and Text To Speech (RAD), the situation model, and the language model.

- **Sensors and Motors.** This module interacts with lower level OPEN-R system calls to control physical motors and obtain information from the camera.
- **Vision.** Receives in real-time a sequence of images from the AIBO camera. Performs the processing necessary to identify objects in the field. The simplest level of recognition involves object identification by color with addition filtering to avoid inconsistencies and for optimization purposes.

- **Localization.** Determine the robot position taking into account goals, field border and markers at the corners of the field. Different algorithms are used to increase the degree of confidence with respect to each robot's position. Robots share this information to obtain a world model.
- **Wireless Communication.** Transfers information between robots in developing a world model or a coordinated strategy. Receives information from the Game Controller, a remote computer sending information about the state of the game (goal, foul, beginning and aim of game) controlled by a human referee. Provides basis for Human-Robot Interaction.
- **Behaviors.** Controls robot motions from programmed behaviors in response to information from other modules, like vision, localization and wireless communication. Behaviors are affected by game strategy, specific role players take, such as attacker or goalie, and by human interaction.
- **Motion.** Receives commands from the behaviors module corresponding to robot actions such as walk, run, kick the ball, turn right or left, etc. These actions control motors in both legs and head.

5.3.4 Define interface agreements

Based on the architecture configuration above, and the dialog model in Figure 5, we will define the new interfaces between the coach and the HRI, and most crucially, the technical interfaces between the HRI and the Aibo(s). The WIRELESS_COMMUNICATION elements in the RAD interface model will perform two interface management functions: They will convert speech commands (defined in 5.3.1) to the OPEN-R formatted Aibo commands, and in turn they will convert OPEN-R Aibo responses into human-understandable sentences that will then by played by the synthesizer.

5.3.5 Test software modules with simulated interfaces

Validate (a) Aibo's ability to receive simulated commands and respond appropriately, and (b) Human-Robot interface ability to send and receive simulated commands and responses, respectively.

5.3.6 Duplicate a single Aibo set-up in Lyon for initial testing

The Lyon group will acquire the Aibo robot with funds from the ACI Neuroscience Integrative et Computationelle.

5.3.7 Integration and test at ITAM

At ITAM´s Robotics Laboratory we have five AIBO robots and are currently in the process of acquiring five new ones.

5.3.8 RoboCup evaluation

We will test the resulting system at RoboCup events by playing against other teams in friendly games. In Mexico there are several teams participating in the AIBO league as well as in Europe and the US.

5.4 Research Plan :

While this work will be done in close interaction between the two research groups, Dominey will be responsible for the natural language aspects while Weitzenfeld will be responsible on robot control.

A. Natural Language (Peter Dominey)
  1. Specification and prototype of communicative constructions.
  2. Specification and prototype of dialog model and interaction protocol.
  3. Specification and prototype of interface agreements.

B. Robot Control (Alfredo Weitzenfeld)
  1. Allocation of communicative constructions, dialog model and interaction protocol to software and hardware.
  2. Software module testing with simulated interfaces and real-time AIBOs.
  3. RoboCup evaluation.

C. Presentations and Publications
  C.1 Presentations: presentation of results at meetings including

International Conference on Intelligent User Interfaces 2006
IEEE-RAS/RSJ International Conference on Humanoid Robots
Competition at International RoboCup

C.2 Publications: in related journals including
Cognitive Systems Research, IEEE Transactions on Systems Man and Cybernetics, Robotics and Automation.

5.5 Project Calendar :

1. Kick-off meeting in Mexico – Scenario Description: Month 1, Duration 1 Week, Objective: Work through simulation examples of all four categories of interactions, identifying the major interfaces, and validating the level 1 architecture. The deliverable will be the Scenario Description Document that includes detailed UML (Unified Modeling Language) descriptions of end-to-end human-Robot interactions, indicating all interfaces, system level calls, etc.
2. Version 2 Functional Description Document preparation: Months 2-6; Duration 4 Months; Objective: Generate a detailed functional description of the human-machine interface, with a detailed account of the structure of the verbal commands and the corresponding robot behavior. (5.4 A.1, A.2)
3. Version 1 System Development: Months 3–6, Duration 3 Months: Objective – Development of a preliminary version of the system that demonstrates reliable end-to-end communication (human user command – system response) for a limited subset of the interaction repertoire. (5.4 B.1)
4. Version 1 Integration & Test: Months 7-8, Duration 2 Months Objective: Integration and test of version 1. (5.4 B.2)
5. Version 2 System and Interface Description Document: Months 7-10, Duration 4 Months; Objective: Finalize architecture and interfaces including the mapping from the different interaction types, and the corresponding predicate-argument robot command and control protocol. (5.4 A.3)
6. Version 2 System Development: Months 9 – 12, Duration 3 Months: Objective – Development of the final version of the system that demonstrates reliable end-to-end communication (human user command – system response) for the interaction repertoire. (5.4 B.1)
7. Version 2 Language Evaluation: Months 11-12, Duration 2 Months Objective: Integration and test of final version (5.4 B.2)
8. Version 2 Integration & Test phase 1 Months 13-14, Duration 2 Months Objective: Integration and test of final version (5.4 B.2)
9. RoboCup Testing: Months 15 – 18, Duration 4 months: Objective - Intense use of the system. (5.4 B.3)
10. Valorization and Publication: Months 19-24: This will include the production of a short documentary science film that can be used by the French and Mexican funding agencies as a demonstration of such a collaborative project. (5.4 C)

5.6 Collaboration Background :

Alfredo Weitzenfeld is the main designer of the Neural Simulation Language (NSL), a system for neural modeling [11]. The work on NSL was started in the early 1990s at the University of Southern California (USC), where an extensive number of biological neural models were developed. Peter Dominey, in his doctoral thesis at USC developed a monkey oculomotor model using the NSL system. His work is included in one of the NSL book chapters [12]. A just recently funded project by CONACYT in Mexico (C03-42440) entitled "Visually-guided NeuroEthological Autonomous Robots: An Adaptive Middleware Approach to Distributed Embedded Mobile Systems" includes an extension to Peter Dominey's original work in the oculomotor systems [13].

5.7 Publications :

Dominey PF, Ramus F (2000) Neural network processing of natural lanugage: I. Sensitivity to serial, temporal and abstract structure of language in the infant. *Lang. and Cognitive Processes*, 15(1) 87-127

Dominey, P.F. (2003a) Learning Grammatical Constructions in a Miniature Language from Narrated Video Events, Proceedings of the 25th Annual Meeting of the Cognitive Science Society, Boston

Dominey, P.F. (2003b) Learning Grammatical Constructions from Narrated Video Events for Human-Robot Interaction, Proc. IEEE Conf. On Humanoid Robotics, Karlsruhe.

Dominey PF (2000) Conceptual Grounding in Simulation Studies of Language Acquisition, *Evolution of Communication*, 4(1), 57-85.

Dominey PF, Hoen M, Lelekov T, Blanc JM (2003) Neurological basis of language in sequential cognition: Evidence from simulation, aphasia and ERP studies, (in press) *Brain and Language*

Weitzenfeld, A., Arbib, M.A., Alexander, A., 2002, The Neural Simulation Language: A System for Brain Modeling, MIT Press.

Weitzenfeld, A., Gutierrez-Nolasco, S., Venkatasubramanian, N., 2003, Controlling Mobile Robots with Distributed Neuro-Biological Systems, Proc. AINS 2003, 2nd Annual Symposium on Autonomous Intelligent Networks and Systems, June 30 – July 3, Menlo Park, California.

Weitzenfeld A., 2003, Embedded Mobile Systems: From Brain Theory To Neural-based Robots, Proc MED '03, 11th Mediterranean Conference on Control and Automation, June 17-20, Rhodes, Greece.

Weitzenfeld A., Gutierrez-Nolasco S., and Venkatasubramanian N., 2003, MIRO: An Embedded Distributed Architecture for Biologically inspired Mobile Robots, Proc ICAR-03, 11th International Conference on Advanced Robotics, June 30 – July 3, Coimbra, Portugal.

Arkin, R.C., Ali, K., Weitzenfeld, A., and Cervantes-Perez, F., 2000, Behavioral Models of the Praying Mantis as a Basis for Robotic Behavior, Journal of Robotics and Autonomous Systems, 32 (1) pp. 39-60, Elsevier.

Work Significance

This collaboration is based on complementary research areas, at ITAM in collaborative robotics systems and at ISC in human-robot interface. This collaboration is highly beneficial.

1. **Scholarship**. Many students graduating from Mexican institutions including ITAM have already continued with advanced degrees in the US and Europe. At the moment, ITAM offers double master programs with École Nationale Supérieure des Télécommunications de Bretagne (ENSTB) and the Institut National des Telecommunications (INT) both in France. We expect in the future to have a program with ISC where ITAM graduates can continue for advanced degrees in robotics related fields.
2. **Science**. Collaborative robotics and human machine interface are two areas of important scientific development. Our current collaboration will extend scientific work by producing advances (and publications) in these two areas.
3. **RoboCup**. RoboCup is a major development where teams from different countries meet at multiple competitions during the year having a major world cup event once a year. At ITAM we started competing two years ago participating at two American Opens in two categories : small-size and AIBO leagues. In the small-size league we obtained 3rd place in 2003 and 2nd place in 2004. In the AIBO league we started to participate only this year. We expect to compete in world cup in 2005 in both leagues. These participations have brought attention to many students throughout Mexico in doing projects and theses in the robotics laboratory at ITAM. Newspapers and TV in Mexico have followed with great interest these participations. This year we are organizing a Latin American RoboCup contest in Mexico and expect to have a Mexican Open starting next year.
4. **Technology**. Human machine interface and its use in the control and monitoring of multiple collaborative robots has significance beyond soccer playing. One of the major application of RoboCup technologies is search and rescue in large scale disaster. RoboCup initiated RoboCupRescue [9] project to specifically promote research in socially significant issues theme related to urban search and rescue (USAR) robotics [8,14]. This technology is starting to have an important impact in countries where earthquakes are common and in response to other related disasters such as the case of the twin towers in New York [10]. We expect work from this proposal to have an ever increasing importance in society, in support of life-threatening as well as other robotic applications.

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