UChile1 Team Description Paper

Javier Ruiz-del-Solar, Juan Cristóbal Zagal, Pablo Guerrero, Paul Vallejos, Christian Middleton, Ximena Olivares, Rodrigo Palma, and Mauricio Borquez

Department of Electrical Engineering, Universidad de Chile
http://www.robocup.cl
{jruizd,jzagal,pguerrer,pvallej}@ing.uchile.cl

Abstract. This document corresponds to our UChile1 Team Description Paper. We are applying for participating in the next Robot Soccer World Cup, RoboCup 2003, under the Sony Four Legged League. As it was requested, this application paper describes our research interest, the proposed approach to address the RoboCup challenge, the background of the principal investigator in our team. We present a description of our team organization, and the effort to be spent. We provide pointers to relevant publications in the context of RoboCup and robotics in general. Finally we present our commitment, in terms of traveling expenses and registration fees for participating in the next RoboCup.

1 Statement of Research Interest

The interest of our group is on mobile robotics, autonomous systems, intelligent systems, and computer vision. We are currently focusing our efforts towards evolutionary robotics and collaborative robotics. We intend to contribute to these research areas by experimenting with groups of intelligent robotics agents, which are able to interact socially, to learn from their own experience and from their direct contact with the real world. Our long-term goal is to develop new approaches for robot machine learning having groups of mobile robots as our main test board. The RoboCup challenge fits perfectly in this context. It allows us to gain and share a great amount of experience in the difficult task of having a group of autonomous robots collaborating in a soccer team under standard game conditions. We consider that in order to improve further the skills of any of such group of robots, it is necessary to incrementally incorporate learning mechanisms aiding the engineering task. We aim at contributing with this great challenge by proposing novel learning strategies on each one of the main issues of the RoboCup four-legged soccer robot problem. As all of us know, the four-legged soccer is a very constrained problem in terms of hardware (camera, processor, available memory, sensors, etc.) and game field, in which many different processing approaches have been already proposed. As a new team in this league we want to specialize us in the introduction of evolutionary, adaptive and collaborative methods for the perception, control and strategy subsystems. For example, in the case of the visual object recognition problem, we have proposed a genetic-based system for the selection and tuning of rules for the detection of the ball, landmarks and goals [5]. We are now using this system for deriving rules for the detection and pose estimation of the robots in the game field. We are also exploring how learning can be applied for improving the strategy of our team. We believe that it is possible to learn from the real interaction between robots, minimizing the simulation on the learning process. Another topic in which we are working on is the adaptive learning of new strategies of localization by minimizing the observational cost (movement path of the robot head). We have one PhD student writing his thesis on evolutionary robotics, and one master student writing her thesis on evolutionary-collaborative robotics. They are using legged robots and the soccer problem for demonstrating and testing their proposed approaches. The main idea is to learn from real game experiences minimizing the simulation. In a near future we are going to explore the evolution of key movements of the robots (not gaits which have been broadly explored[2][3]).

Finally, we would like to express that we have a very good experience in the use of robot contests for fostering research activities on robotics and for motivating the interest of students in the field. In fact our research group was created as a consequence of the *1st IEEE Latin American Student Robotic Contest*, which we organized last year (http://www.ewh.ieee.org/reg/9/robotica/1stRobotContest). We are consolidating this group thanks to the creation of our two robot soccer teams, and our potential participation on RoboCup 2003. We believe it is important that a team of South America would have the opportunity to participate in RoboCup 2003, for spreading robot soccer in a continent with a great potential in research and in which soccer is by far, the most popular sport. Through our work in the *IEEE Latin American Council* (http://ewh.ieee.org/reg/9/robotica/) we have seen an increasing interest of engineering students on robotics. We are organizing the *2nd IEEE Latin American Student Robotic Contest* in Brazil, which will include some robot soccer contests (http://www.ewh.ieee.org/reg/9/robotica/2ndRobotContest).

2 Proposed Approach to Address the RoboCup Challenge

Our system is divided into four task-oriented modules which are vision, localization, strategy, and motor action, see figure 1. The vision module operates on each robot locally. The localization module is distributed, it operates on each robot and a global estimate of the overall localization is generated in a distributed fashion. The strategy module is also separated into a global part, which resides into the goalie player, and also a part which operates locally. The motor action module operates locally on each robot. Another component of our architecture is the wireless inter robot communication system. The following is a description of each one of these modules.

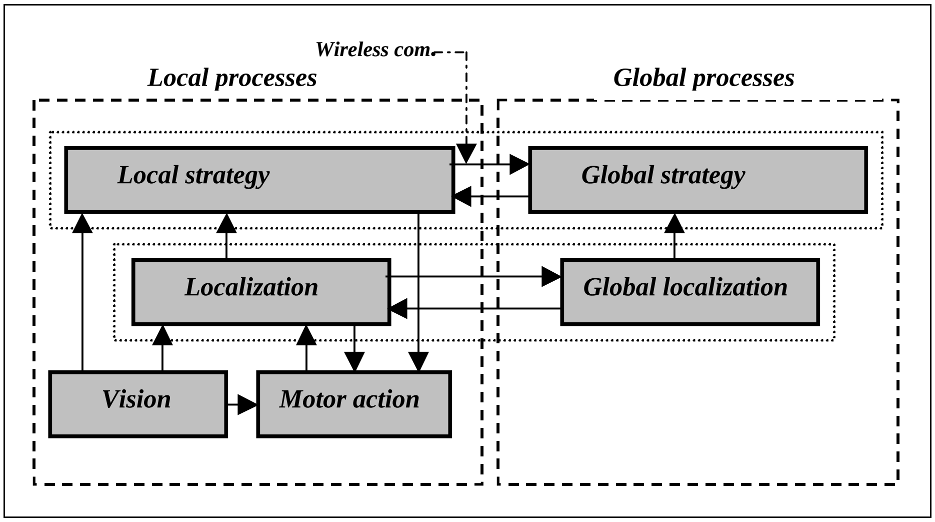

Fig. 1. Modular organization of our system. In the bottom the low level processes of vision, motor action and localization. On top the high level processes of strategy. We distinguish between local process (left) and global processes (right).

2.1 Vision

The vision module takes as input the raw data from the AIBO camera, in the YUV format, and generates a list of the relevant game field objects which are present in the visual field of the camera. These relevant objects correspond to the red or blue robot players, any one of the six colored beacons, the cyan and yellow goals and the orange ball. For each detected object their distance and azimuth, projected over the field plane, are estimated, as well as corresponding confidence degrees for their detection, distance, and azimuth estimations. This module is divided into six processing sub-modules, which are: color segmentation, run-length encoding of the segmented image, labeling of connected regions, region extraction and characterization, rule-based object perception, and finally computation of distances, azimuth and projections of objects over the game field plane.

2.1.1 Color Segmentation

This sub-module takes as input, from the AIBO camera, the raw color image with their three channels Y, U, and V, and generates as output a single channel image containing identifiers for the background and the relevant colors of the game field, which are pink, yellow, green, cyan, blue, red, and orange. We have recently incorporated in this implementation the detection of white. The segmented image is then generated by extracting identifiers from a look-up table of 64 levels in each dimension Y, U and V. The values Y, U and V of each pixel are converted to indexes in the range 0 to 63 for accessing the look-up table values. The user-based color calibration process, which generates the look-up table, consists on first taking pictures from the game field and the environment with the AIBO camera. Then image regions, which are related to the colors of the game field, as well as examples of non relevant colors, which are used for training the background class, are selected within a supervised process. Training a special class for the non-relevant colors is a fundamental consideration in our implementation. Then, these sample pixels are extracted with the color identifier which is provided by the user. These samples are directly located into the look-up table according to their coordinates in the YUV space. This process gives rise to the generation of clusters into the YUV space. We have observed that the shape of these clusters is usually oblong, in general difficult to be characterized in terms of rectangles. Instead of doing so, we just leave these shapes as they are, but we enforce the shape and internal structure of these clusters by applying a median mask over the look-up table values and morphological operators of dilation and erosion over the clusters. Dilation serves for filling in the interior of clusters, while dilation serves for keeping them under their original size. The median mask is used for cleaning up the interfaces between clusters. In general this process requires few images of the game field, and it takes about 15 minutes.

2.1.2 Run-length encoding

This sub-module takes as input the resulting image of the color segmentation sub-module, and generates a run-length codification of the image in the form of an array of 4xN elements, where N is the variable number of segments which are extracted from each frame. A run or segment consists of a set of foreground connected pixels of the same color identifier within the same image row. This codification is generated by scanning the image thought its rows and, for each run or segment, the coordinates x and y of the first pixel are stored in the array as well as the corresponding length of the run. The UNSW team uses this codification [1], we consider that it is particularly useful for reducing the amount of data as well as for simplifying the subsequent labeling stage.

2.1.3 Labeling of Connected Regions

A variant of the connected components labeling algorithm is used for assigning a label to each connected segment, and for defining connected regions on the image. This process takes as input the 4xN run-length codification updating the fourth field of each segment with a corresponding label. This is performed by looking, on each row, the upper neighbors of each segment , and then copying their corresponding labels. If a segment has two upper neighbors having different labels, their corresponding labels are replaced going upwards along each branch. If a segment has no label, a new label is generated. In this process we consider only the foreground segments. Similar labeling processes have been proposed by other teams. We consider that this is a good choice in combination with the run-length codification.

2.1.4 Region Extraction and Characterization

The region extraction sub-module takes as input the run-length encoded and labeled image, and generates a list of regions or blobs which are related to each color. Each region is characterized with a set of region descriptors which are: the coordinates of the region bounding box, the coordinates of the region center of mass, the perimeter of the region, the mass of the region, the color of the region, and other descriptors. These descriptors are afterwards used for the recognition of relevant object into the game field.

2.1.5 Rule Based Object Perception

The task of the object perception sub-module is to identify image regions which are related to the relevant game field objects. The recognition of objects is performed by evaluating the response of a set of rules which are applied over a set of candidate regions or combinations of these candidate regions. For example the detection of a landmark is performed by evaluating the response of some rules to the combinations of regions of the colors pink, cyan, yellow, and green. The detection of the other players into the game field is also performed by applying rules over combination of regions. The detection of a ball usually requires that the related blob has the color of the ball, and if this is not the case one might expect to reject this candidate blob. The rules which are used in our team where derived by using our proposed genetic based method for visual rule selection and parameter tuning [5].

2.1.6 Computation of Distances, Azimuth and Projections

The distances and the azimuth of the objects are initially calculated with respect to the optical axis of the camera. These measures are then projected over the game field plane by simple matrix operations. These transformations are a function of the actual pose, described with three angles, of the robot head.

2.2 Localization

The localization module is divided into two sub-modules which are the global localization sub-module, in charge of generating a global map, and a local localization sub-module in charge of generating estimates of the instantaneous auto localization of each robot. We use the Monte Carlo localization Method for the global localization sub-module. We have selected this method since, among other methods it shows to be less computationally expensive. The Monte Carlo Method allows us to reduce the amount of memory required for the localization function, compared with the grid based Markov localization method, allowing a faster integration of the measurements. The localization which is performed locally is based on the creation of fuzzy sets representing geometrical regions, which are defined from the observations of landmarks and players in the game field. The resulting location, defined with the coordinates *x*, *y*, and the orientation angle *theta*, results from using the center of mass defuzification method. The global localization takes as input the orientation angle and the coordinates from each robot instantaneously as hypothesis points and computes an estimate of the overall localization of the team and opponents with the Monte Carlo Method. In case that the confidence levels are below certain threshold, the localization module is able to send action commands directly to the motor action module. These commands are specifically directed to the robots heads.

2.3 Motor action

The motor action module receives motor commands from the modules of strategy, localization, and even from the vision module. This module is divided in two sub-modules, one in charge of the motion of the head, and one in charge of the motion of the legs. The sub-module in charge of the motion of the legs receives motor commands described with the following three parameters: the *type of movement*, the *number of executions*, and the *speed of execution*. Each type of movement is defined with a matrix where for each joint an itinerary of angle positions is specified. The sub-module in charge of the head motion receives commands of the type: *move to a certain angle*, *move with certain amount of degrees*, etc. The vision module is able to send actions such as *tracking the ball*. It is important to notice that this module is implemented in a behavior-based sense, where a function describes the priority between certain behaviors. For example the *tracking ball* behavior is inhibited when a *kick the ball* behavior is requested.

2.4 Strategy

The strategy is divided into a set of local and global processes, the local processes are performed on each player, and the global processes are performed on the goalie. Figure 2 summarizes the decision tree for a player. The main idea is to decide which movement to perform taking into consideration the position of the player with respect to the ball, the possession of the ball, the position of the other players, the distance to the goal, and so on.

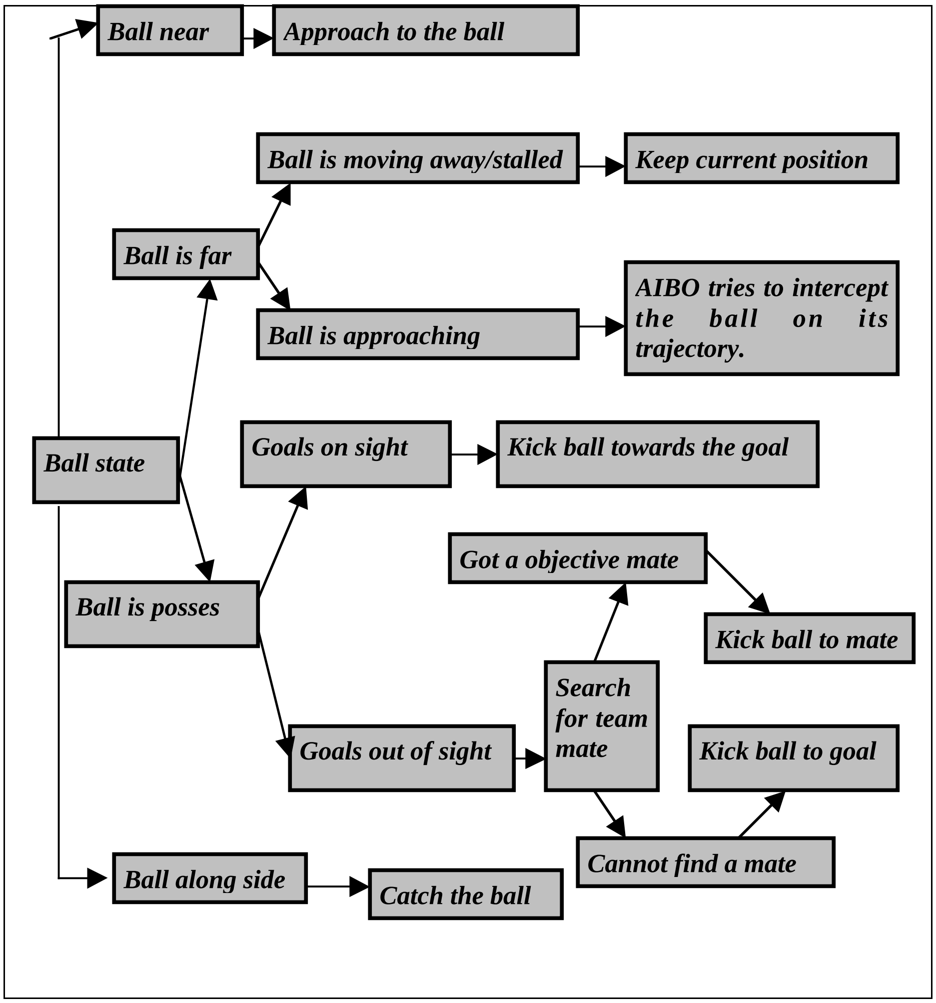

Fig. 2. Illustration of the decision tree which is used for the local strategy of each player.

For the global strategy different regions of action are defined over the game field. These regions are not necessarily overlapped. The captain of the team defines dynamically these zones depending on the game circumstances, as well as the amount of players which are available into the game. It also depends on the situation of the game, for example if the team is wining or loosing.

The local strategy might produce conflicts, for example the player that is located closer to the ball might decide to avoid going towards the ball since it falls outside its corresponding region of action. In this case no one in the team will go towards the ball. This kind of conflicts are detected with the global strategy and new regions can be assigned to the players and new orders are then generated for them.

We are planning to implement a predictive approach for the strategy of our team. This approach uses the previously defined local strategy as a predictor of the behavior of the opponent team players. In this context, the global strategy sub-module is in charge of evaluating the possible behaviors and objectives of the team mate players, which are defined as follows:

- *Behavior:* is a list of motor action commands. A motor action command is defined with the parameters Vx, Vy, α, and t (time). Figure 3 shows an illustration of these parameters. The evaluation of a behavior corresponds to the sum of the parameters t, of the motions that it defines.
- *Objective:* is a possible game action, which might be for example: *Go to the ball, Kick the ball towards the goal, Send ball to a player mate, Intercept the ball, Kick the ball away, Keep away from the game action, Positioning for getting the ball.* The evaluation is dynamic; it is defined on a list of possible game states. This evaluation is expressed in the form of a scalar value K.

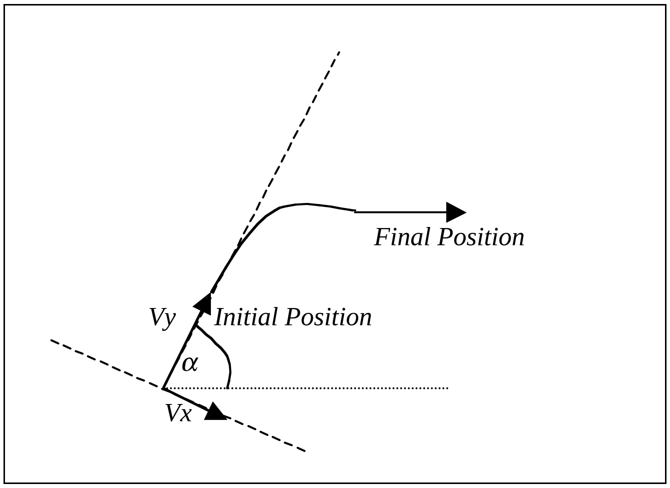

Fig. 3. Illustration of the change in the position and orientation of a robot, before and after a motor command.

If the resulting objective evaluation t and behavior evaluation K gives values which are above to those corresponding to the current behavior under execution, then a new objective-behavior pair is selected for execution. This allows the selection of the best objective and the best corresponding behavior.

2.5 Software development organization

We noticed, from the very beginning of our work, that developing software for the RoboCup Four Legged Challenge also involves establishing a fully organized and scalable working platform allowing the interaction of many people over the same piece of source code. The following are the main considerations that we have taken with respect to the software development organization of our team:

- We use the Concurrent Version System (CVS) to allow many people working over the same source code without having problems while merging versions, as well as having a good managing of the code versions.
- The code organization should exploit the advantages of the open-r object oriented approach; the code is divided into modular pieces under an architecture which allows scalability.
- We have dedicated a great amount of attention to the design of efficient interfaces between the modules.
- The code is written in a way that allows it to be compiled under both Aperios and a debugging platform such as Linux or Windows.
- The code is written in a way that facilitates the incorporation of monitoring tools.

3 Background of the principal investigator

The main background of Prof. Dr. Javier Ruiz-del-Solar is on image processing and computer vision. He has contributed to the fields of *Face Analysis*, *Application of Soft-Computing technologies to Computer Vision and Pattern Recognition problems*, *Texture Analysis*, *Retrieval* and *Synthesis*, and *Robotics and Autonomous Systems* with more than 60 articles published in international journals, conferences and books (see http://www.cec.uchile.cl/~jruizd/publications.html). Since 2002 he serves as technical reviewer of the *IEEE Trans. on Systems, Man and Cybernetics – Part B*, and in the past was reviewer of *Pattern Recognition Letters*.

Since 2002 Prof. Ruiz-del-Solar has been involved in the organization of robotics contests in Latin America and in the increasing of robotics activities in Chile. He is creator and chairman of the *IEEE Latin American Robotics Council* (http://ewh.ieee.org/reg/9/robotica/), creator and director of Electrotechnology Laboratory of the Universidad de Chile (http://etec.li2.uchile.cl/home.html), which includes a robotics laboratory, chairman of *1st IEEE Latin American Student Robotic Contest* (Nov. 29 – 30 2002, Santiago, Chile), chairman of the *2nd IEEE Chilean Student Robotic Contest*, (August 8 – 9, 2003, Santiago, Chile), and organizer of the *2nd IEEE Latin American Student Robotic Contest* (Sept. 13-14, 2003, Bauru, Sao Paulo, Brazil). Regarding the organization of other international scientific events, Prof. Ruiz-del-Solar was chairman of the *2nd International Conference on Hybrid Intelligent Systems - HIS 2002* (Dec. 1-4, 2002, Santiago, Chile), international co-chair of the *6th Online Word Conference on Softcomputing in Industrial Applications - WCS6* (Sept. 2001, Word Wide Web), and has been involved on the organization of more than 10 other international conferences and workshops. Detailed information available on his CV (http://www.cec.uchile.cl/~jruizd/curriculum.html).

4 Description of team organization and effort to be spent

The creation of our robotics lab has caused great interest on the students of our engineering faculty and at many non-Faculty levels, as it was exposed in [4]. As a way of canalizing the increasing interest of our students on robotics activities, last year we decided to create two robotic soccer teams, for participating in RoboCup, from this year on. The teams are for the small-size F180 league and our team of the AIBO four-legged league. In order to achieve this difficult objective, in the four-legged league we started to work in parallel, in several fronts, with a group of 15 undergraduate and graduate students. In a first stage of "setup", one student group was in charge of the compilation of all necessary RoboCup information (official site, leagues information, rules, source codes, simulators, etc.) mainly through Internet. Another group was in charge of building our official soccer field, while a last group was in charge of buying the AIBO robots. After a hard work this stage took about 25 days.

Afterwards we started the second stage that consisted in the research work for writing the algorithms and designing the playing strategies of our team. We organized our team taking into consideration the block diagram of the final system we wanted to implement (see section 2). Our team is captained by a graduate student from our doctoral program on automation. A group of 3 to 4 students is in charge of each one of the systems blocks and a special group is in charge of making simulators. Given that we have 5 groups working in parallel, organizational aspects are very important. We have a hierarchical organization of the work and meetings every two days, whose main objective is to coordinate the work of the team. After months of very hard work, including holidays, we finished this second stage last March.

Since March 15 we are working on the third stage, which can be characterized as "playing, playing and playing". The aim of this stage is to increase the performance of our team by means of intensive experimentation. In this context, we will participate in about one month in the next RoboCup American Open [6]. In the case that we classify for the RoboCup 2003, we will travel one week before the event to Europe for playing some concerted matches with a couple of European teams (as human soccer teams do before a Soccer World Championship).

Participating in RoboCup has been an interesting challenge for us. We built a multidisciplinary team of students, which includes students with different majors like computer science, automatic control, telecommunications, electronics, power systems, signal processing and even physics. These students have been working for free and also during their vacations time. We believe that this group of students will be the basis for the consolidation of our research group on robotics. As a group we want to have the opportunity for demonstrating our skills in this fascinating contest.

5 Pointers to relevant publications

Our relevant publications, technical reports, as well as videos and pictures are available in our official website: www.robocup.cl.

6 Statement of commitment to enter RoboCup-2003 in Padova, traveling expense and registration fee for participation.

We formally declare that in the case we classify for the RoboCup 2003 in Padova, we will assist to the event and we will pay the corresponding registration fee. Our Faculty has already allocated the money for the traveling expenses. Please tell us in the case you need and official letter from our Faculty Dean.

References

[1] Chen, S., Siu, M., Vogelgesang, T., Fai Yik, T., Hengst, B., Bao Pham, S., Sammut, C.: The UNSW RoboCup 2001 Sony Legged Robot League Team. In: Birk, A., Coradeschi, S., Tadokoro, S, (eds.): RoboCup 2001: Robot Soccer World Cup V. Springer-Verlag Berlin, Germany (2002) 39-48.

[2] Hornby, G.S., Fujita, M., Takamura, S., Yamamoto, T. and Hanagata, O.: Autonomous Evolution of Gaits with the Sony Quadruped Robot. *Proceedings of 1999 Genetic and Evolutionary Computation Conference (GECCO).* Banzhaf, Daida, Eiben, Garzon, Honavar, Jakiela, Smith, eds., Morgan Kauffmann, (1999) pp. 1297-1304.

[3] Hornby, G.S., Takamura, S., Yokono, J., Hanagata, O., Yamamoto, T. and Fujita, M.: Evolving Robutst Gaits with AIBO. *IEEE International Conference on Robotics and Automation*. (2000) pp. 3040-3045.

[4] Ruiz-del-Solar, J., Zagal, J.C.: How contests can foster the research activities on robotics in developing countries: Chile a case study. *Submitted to the International Symposium RoboCup 2003.*

[5] Zagal, J.C., Ruiz-del-Solar, J., Guerrero, P., Palma, R.: Evolving Visual Object Recognition for Legged Robots. *Submitted to the International Symposium RoboCup 2003.*

[6] http://www-2.cs.cmu.edu/~AmericanOpen03/main/

[7] http://www.robocup.cl