Cerberus 2003 Team Description Paper

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1 Statement of the research interests

Robotic soccer as first proposed by Mackworth [1] is a challenging research domain that is particularly appropriate for studying a large spectrum of issues of relevance to the development of complete autonomous agents [2] -[4].

The "Cerberus" team made its debut in RoboCup 2001 competition. This was the first international team participating in the league as result of the joint research effort of a group of students and their professors from Bogazici University (BU), Istanbul, Turkey and Technical University Sofia, Plovdiv branch (TUSP), Plovdiv, Bulgaria.

Boğaziçi University has a strong research group in AI. The introduction of Robocup as a unifying theme for different areas of study in autonomous robots has attracted many talented students and has accelerated research efforts with many publications. Currently, the department has teams both in Robocup Sony four legged and rescue simulation leagues and in FIRA Mirosot and KheperaSot leagues. The current research interests are:

- application of machine learning techniques in autonomous robots, especially using reinforcement learning in the development of both single agent and multiagent systems
- development of robust realtime image processing algorithms
- development of algorithms for legged locomotion
- development of neuro-fuzzy systems
- development of novel evolutionary algorithms

In the Robocup Legged league, in the previous years, our team focused on setting up the low level modules, solving basic problems like vision and image processing, together with high level issues like planning and behaviors. However, although some multiagent strategies have been developed, due to limitations in communication hardware, they were not implemented and the above mentioned efforts were restricted to single agents. With the introduction of the wireless LAN capability, starting this year we will concentrate on the realization of multiagent behaviors.

Among the topics to be searched, we have generation of multiagent strategies using reinforcement learning, in which we plan to adapt the methodology we have developed for rescue simulation league [6]. In addition, we will work on multiagent localization in which we want to extend the fuzzy approach we had introduced last year for the single agent [7]. In these studies, we will investigate issues related to communication and cooperation between real physical agents.

We are interested in both improving our previous system and also in adding new capabilities. In terms of software development, we will also concentrate on the improvement of source code.

2 Proposed approach to address the RoboCup challenge

The main goal of our team is to build a research platform, which allows robust and efficient carriage of quadruped AIBO robots playing soccer as a team. Modular software architecture has been adopted and implemented. The main system components (modules) are: Vision, Localization, Planner, Behaviors and Locomotion module.

2.1 Vision module

The developed vision module recognizes different objects on the playground (ball, teammates, opponent players, landmarks, goals etc.) and this information is utilized for finding the positions of these objects and AIBO's own on the field. The image processing algorithms designed for the robotic applications have to comply with the requirement for a real time operation. For this reason we have been working on alternative approaches to find the best method.

In case of color images captured by AIBO's vision system, binary methods can be applied after a preliminary color separation of the pixels. It is our aim to develop a fast and reliable algorithm for performing real time color segmentation on the basis of chromacity of the pixels composing objects' images. We are using two approaches for this purpose.

In the first approach several machine learning methods, including neural networks and decision trees are used for the classification of pixels using training data [8-9]. A special tool that is used for collecting and labeling relevant data has already been developed and used for this purpose.

In the second algorithm we are processing each frame to transform it from the three dimensional - YUV matrix derived from the robot built in TV camera to a one-dimensional one composed by marks of different color blobs. Fast hue and saturation (HS) feature extraction will be obtained directly without an intermediate transformation to RGB format. It can be achieved by introducing a new modified relation between RGB and YUV color representations and applying subsequently the standard RGB - HSV transformation proposed by Rogers [5].

The contour finding algorithm could be combined with filtration of single pixels and lines.

The first step in the segmentation process is object's separation based on its color hue. Each pixel receives a code value that relates it to a specific object. According to our estimation the algorithm will ensure less than 10 ms operating time per image in the game conditions.

The next image processing operation performs limiting of the contour of the objects. The border pixels are fixed by gradient operators and using a scanning mask of 3x3 pixels. The method of contour searching is completed with filtering. The blob's first pixel is discovered by its code value. After segmentation the blob is eliminated from the image. Contour coordinates are temporally saved in an array that helps finding the frame borders localizing the object. The size of the frame gives information about the size of the object (the distance to the object) and the code value informs about their type. All the coordinates are defined in coordinate system of the current image. The above information is further used for updating the local and global maps maintained by each robot.

2.2 Localization Module

Last year we have introduced a novel, fuzzy logic based single agent localization algorithm [9]. This year, our team will work on multi-agent localization. The outline of our new approach is as follows:

Since in the 4 legged league, detection of individual robots is hard, and time consuming, after self localization, every robot would send its location and the location of the ball to a global map, and robots would use this map to find the location of the ball, and decide the game plan according to the positions of their teammates. Due to the nature of the league, our team is homogeneous in both computational resources and physical resources, but in order to benefit from the advantages of heterogeneous multi agent teams, we are going to use heterogeneous role division. So at every role division step, one of the players, who will be less busy according to the current state of the environment, would take the messages from all the teammates, update the global map, and the location of the ball, avoiding false positives, and would send this global map to all teammates. In this way, the others would spend less memory and computational resources, and the overhead of message passing would be minimized. Since the goalie would not be very busy and doing a limited amount of work during most of the game, this is expected to be mainly the goalie’s duty. In case of an attack to the goal area, the robot which is the least busy one (e.g. furthest one away from the ball), would take over this job. The goalie has one more advantage for this task. Since it would be monitoring the field with the widest view point, it would be the most accurate about the position of the ball (if it is not too far), and can eliminate false positives and solve conflicts better than any other player.

2.3 Planner, Behaviors and Locomotion modules

Another area, where we would like to concentrate our further research on are the Behaviors and Locomotion modules.

2.3.1 Single Agent Behaviors

The behaviors module was intentionally separated from the Locomotion module. This allows us to write high-level control rules and behaviors that are relatively independent from the low-level control of the robot. The developed Locomotion module is hardware-dependent, but the behaviors part is hardware-independent and can be easily ported to and from other physical platforms including wheeled mobile robots. The type of the selected behavior and the required information about the environment are considered as input data for the Behaviors module. Its outputs include linear velocities along the principal and lateral axes of the robot, and angular velocity. These are required for the implementation of the robot locomotion.

Some behaviors are relatively simple. Our current interest is to develop more complex behavior that can be classified as intelligent behaviors. We intend to use a specially trained fuzzy-neural network for each intelligent behavior. Until now Ball Interception and Obstacle Avoidance (BIOA) and Reaching Ball from Predefined Direction (RBPD) were developed. Currently a sliding mode strategy for adaptive learning in multilayer feed-forward neural networks is developed [2], [5] and we intend to apply it for learning new intelligent behaviors.

2.3.2 Multiagent behaviors

For the multiagent behaviors we intend to adopt the approach we have developed for the Rescue Simulation league. Each agent has a learning module. The agents learn to choose among the possible actions like dribble, pass, shoot, etc. In addition, they learn which player they must pass first. Reinforcement learning is used as the learning method. Due to the nature of the soccer environment Q-learning has been considered as the most suitable reinforcement learning technique to be used for this task.

A Q-value is the value given to a state-action pair. It determines how successful an agent can be if it does the given action in the given state. In the temporal difference method, at the end of the sequence of actions, the Q-value associated with the initial state-action pair is updated considering two different values. The first value is the external reward obtained, the second value is the Q-values available in the arrived state. If by doing a sequence of actions the agent arrives to a state where there is a high possibility of doing good actions, therefore actions with high Q-values, then the Q-value associated with the initial state-action pair is increased. Since the state of the environment involves the results of the actions of the other agents, the start and end states are not deterministic..

The agents can be run and decide on their actions in two different modes: greedy or explorer. If the agent is running on greedy mode, it always tries the action with the best Q-value so far. If the agent is running in explorer mode, it can accept actions with lower Q-values with a predefined probability, which is the exploration rate. The explorer mode is used during training, and greedy mode is used during real action.

2.3.3 Locomotion

Considerable research efforts are currently directed also to the improvement of the Locomotion module. We are currently rewriting completely the module in order to make the robot walk faster, smoothly and decrease the amount of slippage. In this approach, each of the legs of the dog is considered as a three link manipulator and the four legs have a common base in the center of gravity of the dog. The forward and inverse kinematics tasks have been solved. The control of the head movements is fully independent from the walking. Head motion commands include a set of "scan" commands, "look-at" commands that points the head to a specific direction and "track" command, which solves the object tracking problem. These commands are implemented directly by giving appropriate set-points for the position of the three joints which rotate the head around three perpendicular axes.

The main task, which has to be decided, is to provide stable walking and a possibility for control of the robot's speed and direction. For these purposes an efficient gait has been developed. In every moment the robot is standing on the playground with at least three legs. It moves its legs one by one in the following order: front left, rear right, front right and rear left. This gait provides an acceptable balance between the velocity of walking and stability, which is necessary for the work of the built in TV camera. The control scheme uses the inverse kinematics model of the robot to obtain the desired joint positions. The linear locomotion velocity of the robot can be controlled by changing the size of the steps. The necessary angular velocity is achieved by using different linear velocities to right and left legs.

3 Background of the principal investigator

Cerberus is a multinational team with two co-directors one from Turkey and one from Bulgaria

The acting Cerberus team leader and National Coordinator for the participants from the Department of Computer Engineering, Boğaziçi University, Turkey is Dr. H. Levent Akın.

Dr. Akın received B.Sc degree in Aeronautical Engineering from Istanbul Technical University in 1982 and MSc and PhD degrees in Nuclear Engineering from Boğaziçi University in 1984 and 1989 respectively. Since 1989 he is a faculty member in the Department of Computer Engineering, Boğaziçi University where he is currently an associate professor. Dr. Akın is an active researcher in autonomous robots field. He is currently leading several teams that participate in both Robocup and FIRA organizations. He is a member of the Robocup 2003 organization committee for Rescue Simulation League.

The National Coordinator for the participants from the Department of Control Systems, Technical University of Sofia, Plovdiv branch, Plovdiv, Bulgaria is Dr. Andon Venelinov Topalov.

Dr. Topalov received the M.Sc. degree in Control Engineering from Moscow Higher Institute of Civil Engineering, Faculty of Control Systems (Moscow, Russia) in 1979 and the Ph. D. degree in Control Engineering from Moscow Higher Institute of Mining Engineering (Moscow, Russia) in 1985. Since 1986 he is a faculty member in the Department of Control Systems, Technical University of Sofia, branched at Plovdiv (Plovdiv Bulgaria) where his focus in research is on pattern recognition and intelligent control of autonomous systems. He is currently visiting assoc. professor in the Department of Electrical and Electronic Engineering, Bogazici University. In 1995-96 he spent one year in the School of Electrical Engineering at Korea Advanced Institute of Science and Technology (Taejon, South Korea) as a post-doctoral fellow. In 1999-2000 he spend as a visiting researcher 7 months in the Intelligent Robotics and Automation Lab, National Technical University of Athens (Athens, Greece) and 9 months in the Mechatronics Lab., Department of Electrical and Electronic Engineering, Bogazici University (Istanbul, Turkey). Before joining Technical University, 16 years ago, he was a research fellow in the Research Institute for Electronic Equipment (Plovdiv, Bulgaria).

The Cerberus team honorary leader and manager is Professor Dr. Okyay Kaynak.

Prof. Kaynak received the B.Sc. degree with first class honors and Ph.D. degrees in electronic and electrical engineering from the University of Birmingham, UK, in 1969 and 1972 respectively. From 1972 to 1979, he held various positions within the industry. In 1979, he joined the Department of Electrical and Electronics Engineering, Bogazici University, Istanbul, Turkey, where he is presently a Full Professor. He served as the Chairman of the Computer Engineering Department for three years, of the Electrical and Electronic Engineering Department for two years and was the Director of Biomedical Engineering Institute for one year. Currently, he is the UNESCO Chair on Mechatronics and the Director of Mechatronics Research and Application Centre. He has hold long-term Visiting Professor/Scholar positions at various institutions in Japan, Germany, U.S. and Singapore. His current research interests are in the fields of intelligent control and mechatronics. He has authored three books and edited five. He has also authored or coauthored more than 200 papers that have appeared in various journals and conference proceedings. Dr. Kaynak is a fellow of IEEE and currently the President of the IEEE Industrial Electronics Society. He serves as an Associate Editor of both the IEEE Transactions on Industrial Electronics and the IEEE Transactions on Neural Networks and additionally he is on the Editorial or Advisory Boards of a number of scholarly journals.

4 Description of the team organization and effort to be spent

Cerberus was the only international team in the Sony Legged League during RoboCup 2001 and RoboCup 2002. The cooperation between the Turkish and Bulgarian participants is mainly through the internet and during the past two years only for a brief period of time just before RoboCup the teams were able to work together in person. The general strategy was to divide the robot software into five major modules and assign a working group for each. Some modules were assigned to two groups at the same time. These modules were locomotion module, localization module, vision module, behaviors module and planner module. Special emphasis was given to the vision and locomotion modules. Until this year the final integration was done during the last ten days before the competition when the entire international team worked together.

During this year we are currently trying to introduce some changes in the organization of the work. Both the Turkish and Bulgarian groups of participants will try to fully integrate all software modules at their work place at an earlier stage. We will try to organize a workshop where the Turkish and Bulgarian participants of the team will be able to work together at a much earlier stage, possibly at the end of April. It is believed that it will allow each group to have better understanding what the other group is doing and will help us to work out a better team strategy. We also assume that as a result of the new changes introduced it will be quite possible to have at our disposal two different complete versions of the robotic soccer software before the RoboCup 2003 competition – the one developed by the Turkish participants and the second of the Bulgarian participants. So, we will evaluate them in order to approve the better one that will be used to compete in Padova. In case both versions will have their own strong sides it will be also possible to adopt a strategy allowing different robots on the field to be equipped with different version of the software, or to switch between the two available software versions when playing games against different adversaries during the competition rounds.

5 Pointers to relevant publications.

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

It is the intention of both parties (BU and TUSP) to enter RoboCup-2003 as an international team and we hereby commit to it. We believe that as the only bi-national team in the Legged Robots League that has already participated in RoboCup-2001 and RoboCup-2002 we will be able to continue our participation in RoboCup-2003.

With regards to the finances, the Cerberus team has already attracted significant attention of the media both in Turkey and Bulgaria. Many local and national newspapers, radio and TV stations have broadcasted information about our work and the international competitions organized by the Legged Robots League within RoboCup initiative. The bi-national nature of the team, representing a somewhat south-to south collaboration has appeared attractive and it appears that with the time going on we will be able to get more financial support in Turkey and to some extend in Bulgaria, too. We also believe that it will be noticed by the funding agencies that this tele-collaborative effort, with its socio-technical aspects may set an example for such future collaborations. It is the intention of the both sides to develop the idea (bi-national teams tele-collaborating) further in a European Mechatronics Design Network that emphasizes East-West, North-South collaboration and a special competition that deals with team performance rather than just the design outcome.

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