Kouretes+AUEBo 2008
Aibo Standard Platform League

Kouretes[1] and AUEBo[2]

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Abstract. Kouretes+AUEBo 2008 is a joint team participating in the Aibo division of the RoboCup Standard Platform League at Robocup 2008. This paper describes various aspects of the team.

1 Team History

Team Kouretes+AUEBo 2008 is a joint effort of two research groups based in Greece. Even though the two groups started independently, the shortage of Aibo robots in the last two years and the recent change of league rules [1], brought the two teams together in a decision to join robot-power and man-power.

Team Kouretes was founded in February 2006 by Michail G. Lagoudakis and became active in the Four-Legged league. In January 2007, under the leadership of Nikos Vlassis team activities were extended to the Simulation league. The team had its first exposure to RoboCup at the RoboCup 2006 event in Bremen, Germany, where it participated in the Technical Challenges of the Four-Legged league. At that time, Aibo programming by the team was done exclusively in an interpreted language, the Universal Real-Time Behavior Interface (URBI), without any use of existing code. Subsequent work led to the participation of the team in the Four-Legged league of the RoboCup German Open 2007 competition in Hannover, Germany. The software architecture of the team was developed on the basis of previously released code by GT2004 and SPQRL 2006. The tournament included ten teams from all over the world. Kouretes reached the quarterfinals round, where it was defeated by the 2006 World Champion Nubots. The team ranked in the $7^{th}/8^{th}$ place in a tournament featuring the team's first win and first goals. In Spring 2007, the team began working with the newly-released Microsoft Robotics Studio (MSRS). The team's software was developed from scratch exclusively in C# and included all the required services, as well as the motion configuration files for the simulated RobuDog robot of RoboSoft. The team's participation in the MSRS Simulation Challenge at RoboCup 2007 in Atlanta led to the placement of the team at the 2^{nd} place worldwide bringing the first trophy home. The tournament involved nine teams from all over the world; Kouretes was the only European participating team. In October 2007, Team Kouretes and Team Cerberus (Turkey) were invited to play friendly demonstration games for the public during the international business meeting Hi-Tech Innovators Partenariat 2007 in Thessaloniki, Greece. This two-day event marked the first time full RoboCup games under the official rules were played in Greece. In May 2008, Team Kouretes was invited to Rome, Italy by Team SPQR to play friendly demonstration games for the public at the TechnoTown Museum and to participate in RomeCup 2008. Detailed information about the team, including pictures and videos, may be found at the team's site `www.kouretes.gr`.

Team AUEBo was founded in Spring 2007 by Diomidis Spinellis at the Athens University of Economics and Business, when four Aibo robots were acquired to equip the Information Systems Laboratory of the Department of Management Science and Technology. Even though the team is just entering the RoboCup community, the Aibos have been already used as academic and research tools in various student projects ranging from human computer interaction to distributed software architectures and ubiquitous computing. Further information about the Information Systems Laboratory and its range of activities may be found at the lab's web site at `istlab.dmst.aueb.gr`.

2 Team Leadership

Michail G. Lagoudakis is an assistant professor with the Division of Computer Science of the Department of Electronic and Computer Engineering at the Technical University of Crete since 2005. He received his Ph.D. degree from Duke University, USA in 2003 and was a postdoctoral researcher at the Georgia Institute of Technology, USA until 2005. His research experience in robotics spans several areas: path planning, motion control, reinforcement learning, coordination.

Nikos Vlassis is an assistant professor with the Division of Production Systems of the Department of Production Engineering and Management at the Technical University of Crete since 2007. He received his Ph.D. degree from the Technical University of Athens, Greece in 1998 and was an assistant professor with the University of Amsterdam, Netherlands until 2006. His current research interests include stochastic optimal control, unsupervised learning, and reinforcement learning. Vlassis has extensive experience with the RoboCup Simulation league and various distinctions with the UvA Trilearn robot soccer team, including the 1^{st} position at the RoboCup world championship (2003), three times 1^{st} position at the German Open tournament (2003, 2004, 2005), and the 1^{st} position at the American Open tournament (2003).

Diomidis Spinellis is an Associate Professor in the Department of Management Science and Technology at the Athens University of Economics and Business, Greece. His interest in autonomous robotics stems from his extensive experience in ubiquitous and distributed software systems. He holds an MEng in Software Engineering and a PhD in Computer Science both from Imperial College London. He is currently the director of the Information Systems Technology Laboratory and the head of the Software Engineering and Security (SENSE) group. Spinellis is a FreeBSD committer and the author of many books, open-source software packages, libraries, and tools. He is now leading the EU-funded SQO-OSS cooperative research project, a software quality observatory for open-source software.

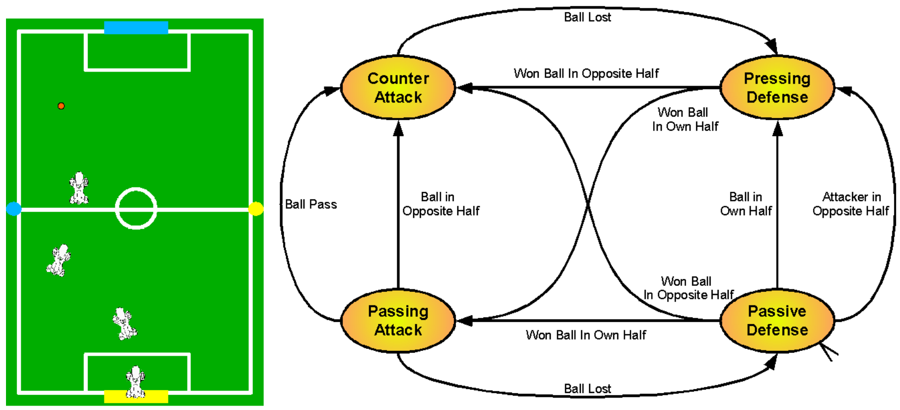

Fig. 1. The Passive Defense tactic (left) and the FSM for switching tactics (right).

3 Team Members

Team Kouretes+AUEBo 2008 includes five members from the two institutions. The brackets indicate the main area each member is working on.

1. Andreas Panakos, undergraduate (TUC) [Image Processing]
2. Alexandros Paraschos, undergraduate (TUC) [Skills and Locomotion]
3. Georgios Pierris, undergraduate (TUC) [Localization]
4. Chris Lazaris, laboratory staff (AUEB) [Communication]
5. Kimon Fountoulakis, undergraduate (AUEB) [Software Architecture]

The robotic personnel consists of 8 Sony ERS-7 Aibos (4 from each institution).

4 Team Research

The team's research focuses on team coordination, robust visual recognition, reinforcement learning, and distributed information sharing. Below, we describe the main points of our work on team coordination and visual recognition.

4.1 Team Coordination

Team formations, tactics, and strategies is largely an unexplored area in the four-legged robocup research. In our work, we took a radical step in behavior control and implemented robot soccer strategies, which are based on human soccer strategies used in real soccer games [2]. Considering that the ultimate goal of RoboCup is a game between robots and professional human football players, we believe that our work takes a step towards this goal.

According to our coordination scheme, the strategy of the team is realized using tactics with well-defined roles for each player. So far, we have defined

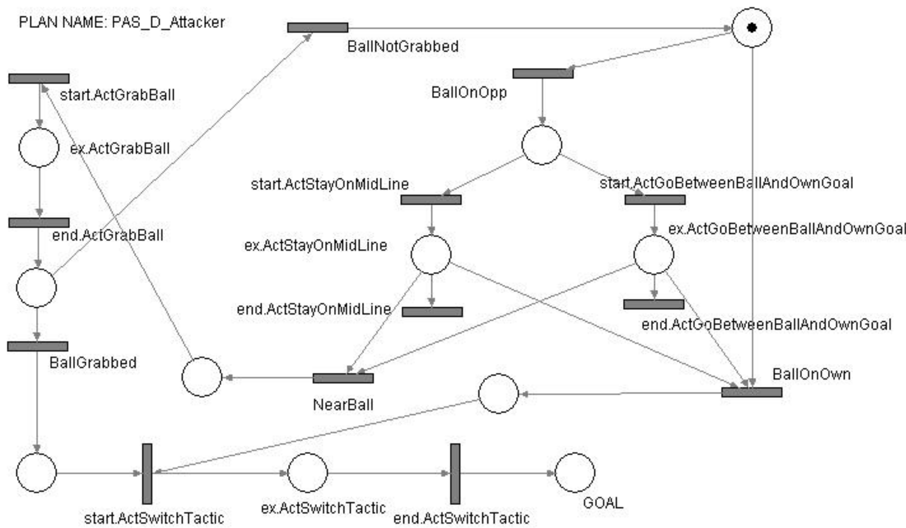

Fig. 2. Petri-net plan for the Attacker role in the Passive Defense tactic.

and implemented four tactics: Passive Defence, Pressing Defence, Counter Attack, Passing Attack. There are four roles in each tactic: Attacker, Midfielder, Defender, Goalkeeper. Each role in each tactic is implemented using Petri-Net Plans [3]. Figure 2 shows the plan for the Attacker role in the Passive Defense tactic (Figure 1), which is defined as follows:

ATT While the ball is inside the opponent's half of the field, the Attacker moves along the middle line and places himself between the ball and the own goal. As soon as the ball enters his own, the tactic switches to Pressing Defense.

MID The Midfielder supports the Attacker by staying behind him visually tracking the ball at all times.

DEF The Defender stays between the ball and the own goal in front of his own penalty line.

A finite state machine, shown in Figure 1, combined with a player communication scheme is used to decide the team tactic and player roles at each time depending on the current position of the ball in the field and the location of each player. This work resulted in improved team play with better field coverage [4].

4.2 Robust Visual Recognition

The main sensor used by the Aibo robots is the CCD camera. The robots rely on visual information to isolate particular colors, identify objects of certain shape in the field, and estimate their distance. Our work focuses on adding robustness to visual recognition against object occlusion and faulty color segmentation. In particular, we suggest a uniform approach for recognizing the key objects in the

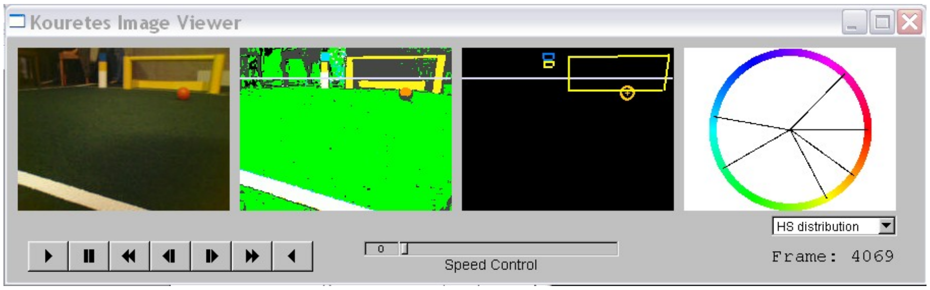

Fig. 3. Histogram-based visual object recognition: camera image, segmented image, recognized objects, color separation.

RoboCup 2008 field: the two goals, the two beacons, and the ball. Our method processes the color-segmented camera image and delivers the type, as well as an estimate of the distance and the angle with respect to the robot, of each recognized object in the current field of view. Figure 3 shows an example of recognizing the ball, a beacon, and a goal in the same camera frame.

Our approach is based on a number of procedures which are used uniformly for all three types of objects: (a) horizontal and vertical scanning of the image, in directions parallel and perpendicular to the horizon line, (b) identification of large colored areas through a finite state machine, which permits a specific tolerance of non-colored pixels within the colored areas, (c) clustering of colored areas through histograms, which expose the density of the colored areas and give an indication of their extent, (d) formation of a bounding box indicating possible presence of an object, and (e) customized filtering based on ratio and distance specifications for removing implausible indications. Then, after a series of transformations using the robot head pose, the object dimensions within the image, the camera parameters, and the real world dimensions of the objects, an estimate of the distance and the orientation to each object with respect to the robot is computed. The key step in this procedure is the use of histograms to represent the distribution of the target color along the various scan lines over the image. All large colored parts (if found) are grouped into a single structure that reveals their density along the scanning direction. Each histogram is a discretization of the entire viewing angle along the scanning direction and the value of each interval indicates the number of overlapping large parts at that particular angle. The peak of the histogram indicates the highest density of large parts along the scanning direction. Identification of the histogram peaks leads to correct recognition of some features of the field objects, such as a vertical goal post.

As a specific example, the recognition procedure for goals aims at recognizing the vertical and the horizontal goal posts separately. To this end, the image is first scanned horizontally in its entirety using 40 uniformly-distant horizontal scan lines and the large parts found are collected into the horizontal histogram. A peak in this histogram (if any) above a prespecified threshold (10% of the total

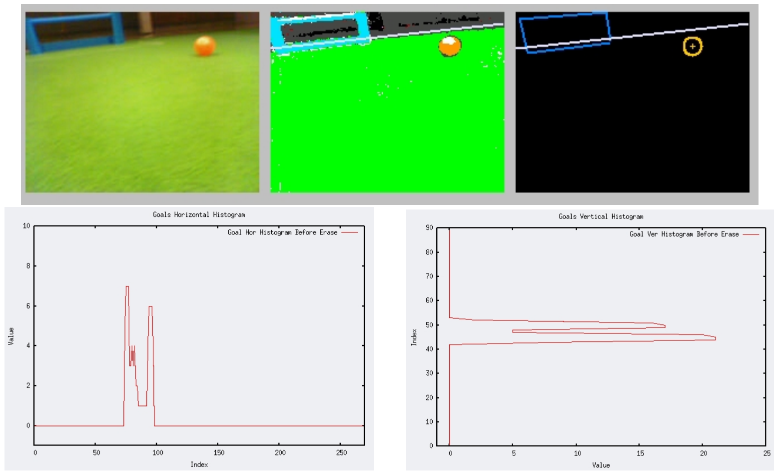

Fig. 4. Goal recognition: raw image, color-segmented image, recognized objects

number of scan lines) indicates the presence of a vertical post. If two peaks are found, then both vertical posts are visible and the entire goal is contained within the image (horizontally, at least); in this case, the horizontal goal indication extends between the two posts and receives high confidence on both sides. If only one peak is found then only one vertical post is visible and therefore the goal is only partially visible in the image; in this case, the horizontal goal indication extends from that post to the appropriate end of the image as indicated by the density of large parts and receives high confidence only on the side of the vertical post. If no peaks are found, then either no goal is currently visible in the image, or the robot is so close to the goal that only sees the central goal part in the image; in these two cases, either no horizontal goal indication is formed at all, or the one formed comes with a low confidence. The procedure continues with a vertical scanning using 50 uniformly-distant vertical scan lines that extend only above and below the horizon to a fixed viewing angle (± 30 deg). This is dictated by the fact that the goals lie around the horizon line and cannot be far away from it. Note that if the current pose of the robot is such that the horizon line is not visible, vertical scanning may not take place at all, if no vertical scan lines lie within the image. Vertical scanning proceeds exactly as the horizontal one, accumulating large parts into the vertical histogram and identifying two, one, or no vertical goal posts as before. A vertical goal indication is similarly derived from the vertical scanning with the appropriate confidence level. During the final goal recognition phase, it is decided whether the horizontal and vertical indications can be combined to offer a single goal indication (a bounding box). Three filters are used to reject implausible indications: (a) the confidence filter rejects indications that come with low horizontal and vertical confidence, that is, no goal post has been identified; (b) the ratio filter rejects indications that come with high confidence, but their horizontal vs. vertical size ratio fails to comply (within an interval) to the true size ratio of the real

Table 1. Recognition performance of the proposed and other approaches.

Object	Approach	True Positives	False Negatives	True Negatives	False Positives
Goals	Kouretes	**61%**	**39%**	**93%**	**7%**
Beacons	Kouretes	**34%**	**66%**	**99%**	**1%**
	GT2004	28%	72%	99%	1%
	SPQRL2006	31%	69%	99%	1%
Ball	Kouretes	**79%**	**21%**	**100%**	**0%**
	GT2004	67%	33%	99%	1%
	SPQRL2006	51%	49%	100%	0%

goal; and, (c) the distance filter rejects indications that yield an invalid distance estimation (negative or larger than the field size). If a set of indications passes successfully through these filters, the combined indication is used to determine the distance and the angle of the recognized object with respect to the robot body and the resulting information is passed to the higher level of cognition. The entire procedure is repeated in a interleaved manner for both the skyblue and the yellow colors. Figure 4 shows an instance of successful goal recognition along with the corresponding horizontal and vertical histograms. The two peaks in each histogram indicate the corresponding goal posts.

Recognition of the beacons and the ball is based on similar ideas, however they are not described in detail here due to space limitations. Our approach was compared against the approaches of two RoboCup teams (German Team 2004 and SPQR-Legged 2006) and is shown to be equally good or better in many cases. It was not possible to compare goal recognition, since the present goals have been introduced in 2007 and are significantly different than those used in previous RoboCup competitions. The statistics of object recognition using all approaches are shown in Table 1. Evaluation is based on three log files recorded during the RoboCup German Open 2007 competition totalling several hundreds of frames.

5 Team Education

Student members of the team have the opportunity to receive formal training on RoboCup-related topics through a number of courses offered by the team leaders. Most of these courses include semester-long hands-on laboratory sessions with Aibo robots, robot arms, and robot simulators, where the students learn how to use various programming tools (URBI, R-Code, Open-R, Tekkotsu, Pyro) and high-level languages (C#, C++, C, matlab) to program robots to perform various tasks. These courses are complemented by a weekly meeting for keeping up with the latest developments within the team and in the community, in general. In addition, our RoboCup teams provide a venue for students to complete their diploma or M.Sc. thesis while being members of the team. Two diploma theses were completed recently [4, 5].

6 Team Software

The team's software architecture is an offspring of the software architecture released by team SPQR-Legged 2006 (Italy), which in turn is an offspring of the software architecture of the German Team 2004 (Germany). The architecture inherits the structural modularity designed by GT2004, however it is written entirely in C++ and is Linux-oriented. The following table shows the origin of the modules we currently use and their current status.

Module	**Original Code**	**Current Code**
ColorTable	SPQR2006	Kouretes+AUEBo2008
ImageProcessor	SPQR2006	Kouretes+AUEBo2008
BallLocator	GT2004	GT2004
SelfLocator	SPQR2006	SPQR2006 and Kouretes+AUEBo2008
BehaviorControl	SPQR2005	SPQR2005 and Kouretes2007
WalkEngine	SPQR2006	GT2005
SpecialActions	GT2004	GT2004 and Kouretes+AUEBo2008
HeadControl	SPQR2006	SPQR2006 and Kouretes+AUEBo2008
Communication	GT2004	GT2004 and Kouretes+AUEBo2008
Tools	SPQR2006	SPQR2006 and Kouretes+AUEBo2008

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