AGILO RoboCuppers 2003: Computational Priciples and Research Directions

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Abstract. This paper gives an overview about the approaches chosen by the middle size robot soccer team of the Munich University of Technology, the AGILO RoboCuppers. First a brief sytem overview will be given. Then the computational priciples are described. Finally the directions for further research are outlined.

1 System Overview

The AGILO RoboCup team [1] is realized using inexpensive, off the shelf, easily extendible hardware components and a standard software environment. The team consists of four Pioneer I robots. Each robot is equipped with a single onboard linux computer, a wireless ethernet for communication, and several sonar sensors for collision avoidance. A color CCD camera with an opening angle of 90^o is mounted fix on the robot. The robot also has a guide rail and a kicking device. That enables the robot to dribble and shoot the ball.

The incoming video stream from the CCD camera is processed by the *vision-based cooperative gamestate estimation module*, which computes the *belief state* of the robot with respect to the game situation. The action selection module then computes an abstract feature description of the estimated game state that can be used to recognize relevant game situations. The *situated action selection module* selects action based on a limited horizon utility assessment. The following sections detail the software design and the operation of these software components.

The game state estimators of the AGILO robots maintain a belief state that contains the respective robot's belief about the current game situation [10]. The belief state includes the estimated positions and orientations of the robot itself, its team mates, the ball, and the opponent robots and provides the information that is necessary for selecting the appropriate actions. State estimation is an iterative process where each iteration is triggered by the arrival of a new piece of evidence, a captured image or a state estimate broadcasted by another robot. The state estimation subsystem consists of three interacting estimators: the self localization system [5], the ball estimator [7, 6], and the opponents estimator [9]. This decomposition of game state estimation into specialized estimation problems reduces the overall complexity of the state estimation process and enables the robots to exploit the structures and assumptions underlying the different subtasks of the complete estimation task.

Throughout the game the AGILO robots have a fixed set of tasks with different priorities. The tasks are *shoot the ball into the goal*, *dribble the ball towards the goal*, *look for the ball*, *block the way to the goal*, *get the ball*, ... The situated action selection module enables the robots to select a task and to carry out the task such that in conjunction with the actions of the team mates it will advance the team's objectives the most. We consider a task to be the intention of the AGILO robot team to perform certain actions. Action selection and execution is constrained by (1) tasks being achievable only if certain conditions hold (eg, the robot has the ball) and (2) a robot being able to only execute one action at a time. The most salient features of the situated action selection are the following ones. First, to realize a competent and fast task assignment and execution mechanism the AGILO controllers make ample use of automatic learning mechanisms [4, 2, 3]. Second, the task assignment mechanism works distributedly on the individual robots and are robust against communication corruptions. Finally, the task assignment and execution mechanism always produces purposeful behavior and always aims at the achievement of high priority tasks.

2 Current Research Directions

At the current development state of the AGILO autonomous robot soccer control system, our most important research directions include the following ones.

- **RoboCup without color labeling.** Most object recognition and localization methods in RoboCup work on color segmented camera images. Unfortunately, color labeling can be applied to object recognition tasks only in very restricted environments, where different kinds of objects have different colors. To overcome these limitations we propose an algorithm named the Contracting Curve Density (CCD)[8] algorithm for fitting parametric curves to image data. The method neither assumes object specific color distributions, nor specific edge profiles, nor does it need threshold parameters. Hence, no training phase is needed. In order to separate adjacent regions we use local criteria which are based on local image statistics. We apply the method to the problem of localizing the ball and show that the CCD algorithm reliably localizes the ball even in the presence of heavily changing illumination, strong clutter, specularity, partial occlusion, and texture[7, 6].
- **Designing complex state estimation systems.** In many autonomous robot applications robots must be capable of estimating the positions and motions of moving objects in their environments. We apply probabilistic multiple object tracking to estimating the positions of opponent players in autonomous robot soccer. We have extended an existing tracking algorithm to handle multiple mobile sensors with uncertain positions.
- **Learning high performance state estimation routines.** Complex probabilisitic state estimation systems have many parameters that need to be adjusted in order to achieve the required robustness and accuracy. The parameters that need to be set include probabilistic observation and action models, predictive models for the expected information content of new observations, the adequate assignment of computational resources to subtasks, and so on. In our research we investigate how the proper setting of these parameters can be learned from experience. To do so, we have developed a global state estimator using a ceiling camera that provides us with the ground truth data for game situations. Using the ground truth data as an oracle of what the state estimator should have perceived, we can then learn situation-specific

probabilistic models of our state estimation system that can be used to improve the system performance.

– **Integration of programming and learning.** Many reasoning tasks in autoonomous robot soccer are so difficult that they can neither be completely programmed nor completely learned. An obvious solution is the proper integration of programming and learning mechanisms. To this end, we have extended the robot control language RPL with constructs for explicitly representing (1) the physical system that is to be controlled and (2) the learning problems to be solved. In the extended language entities such as control tasks, process models, learning problems, and data collection strategies can be represented explicitly and transparently, and become executable. In the learning and execution phase, the entities are first class objects that control programs cannot only execute but also reason about and manipulate. These capabilities enable robot learning systems to dynamically reorganize state spaces and to incorporate user advice into the formulation of learning problems. The extensions that we have presented are expressive enough to rationally reconstruct large parts of the AGILO 2001 action selector.

References

1. M. Beetz, S. Buck, R. Hanek, T. Schmitt, and B. Radig. The AGILO autonomous robot soccer team: Computational principles, experiences, and perspectives. In *First International Joint Conference on Autonomous Agents and Multi Agent Systems (AAMAS) 2002*, pages 805–812, Bologna, Italy, 2002.
2. S. Buck, M. Beetz, and T. Schmitt. Approximating the Value Function for Continuous Space Reinforcement Learning in Robot Control. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2002*, Lausanne, pages 1062–1067, 2002.
3. S. Buck, M. Beetz, and T. Schmitt. M-ROSE: A Multi Robot Simulation Environment for Learning Cooperative Behavior. In *Distributed Autonomous Robotic Systems 5, Lecture Notes in Artificial Intelligence (LNAI)*. Springer-Verlag, 2002.
4. S. Buck, U. Weber, M. Beetz, and Th. Schmitt. Multi robot path planning for dynamic evironments: A case study. In *International Conference on Intelligent Robots and Systems (IROS)*, 2001.
5. R. Hanek and T. Schmitt. Vision-based localization and data fusion in a system of cooperating mobile robots. In *International Conference on Intelligent Robots and Systems (IROS)*, pages 1199–1204, Takamatsu, Japan, 2000.
6. R. Hanek, T. Schmitt, S. Buck, and M. Beetz. Fast image-based object localization in natural scenes. In *International Conference on Intelligent Robots and Systems (IROS)*, Lausanne, Switzerland, 2002.
7. R. Hanek, T. Schmitt, S. Buck, and M. Beetz. Towards robocup without color labeling. In *6th International Workshop on RoboCup (Robot World Cup Soccer Games and Conferences)*, volume 6 of *Lecture Notes in Computer Science*. Springer-Verlag, 2002.
8. Robert Hanek. The Contracting Curve Density Algorithm and its Application to Model-based Image Segmentation. In *Proc. IEEE Conf. Computer Vision and Pattern Recognition*, pages I:797–804, 2001.
9. T. Schmitt, M. Beetz, R. Hanek, and S. Buck. Watch their moves: Applying probabilistic multiple object tracking to autonomous robot soccer. In *AAAI National Conference on Artificial Intelligence*, pages 599–604, Edmonton, Canada, 2002.

10. T. Schmitt, R. Hanek, M. Beetz, S. Buck, and B. Radig. Cooperative probabilistic state estimation for vision-based autonomous mobile robots. *IEEE Trans. on Robotics and Automation*, 18(10):–, 2002.