CS Freiburg 2001*

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1 Introduction

The research work of CS Freiburg in the recent years has resulted in a number of reliable system components. In particular for the self-localization and object-recognition techniques based on laser range finders [4,11], our world-modeling and the cooperative sensing method [4,12,2] and the reactive path planner [10] we only consider minor modifications this year.

Nevertheless we still see room for improvement in several research areas. We intend to integrate new vision hardware and to improve our vision component by employing approaches for adaptive vision. With an upgraded robot hardware we aim for improving the basic skills and to add new ones, particularly for ball intercepting and passing. In the area of action selection we will further explore the capabilities of extended behavior networks [3,7]. We also plan to refine our multi-agent-coordination approach.

2 Team Development

Professor *Bernhard Nebel* is head of the team. The research assistants *Thilo Weigel* and *Alexander Kleiner* design the new team's features and coordinate the development process. *Steffen Gutmann* supports the team in the final development phase. The following graduate students work on improving components of the system: *Markus Dietl* is responsible for world modeling and basic skills, *Patrick Stiegler* for the *vision component* and *Florian Diesch* for action selection. *Boris Szerbakowski* from SICK AG is in charge of the robots' assembly and maintenance.

3 Robots

The CS Freiburg team for RoboCup 2001 consists of *Pioneer 1 robots* as field players and a *Pioneer DX-2* robot as goalkeeper. To make the Pioneer 1 robots more robust and faster we exchanged their controller boards with the ones used in the Pioneer DX-2 robots. Each robot is equipped with a *SICK laser range finder* for self-localization and recognition of robots. The laser range finders provide depth information for a 180° field

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of view with an angular resolution of $0.5°$ and an accuracy of 1 cm. The field players perceive the ball with a *Sony DFW-V500 digital camera*, whereas the goalkeeper uses the *Sony EVI-D30 pan-tilt camera* in conjunction with the *Imagenation PXC 200 frame grabber*. For local information processing the field players are equipped with *Sony Vaio PCG-C1VE notebooks*, which connect to the cameras directly through a IEEE 1394 interface. The goalkeeper uses a *Toshiba 110CT Libretto* and the on-board computer of the Pioneer DX-2. For communication between the robots the *Lucent Technologies WaveLan 11 Mbit/s radio ethernet (2.4 GHz)* is employed.

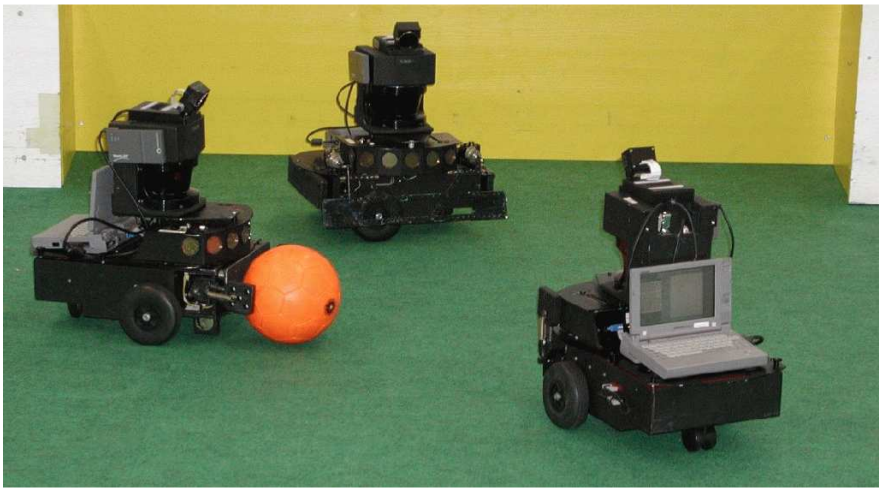

Fig. 1. The CS Freiburg players

For ball manoeuvring we enhanced the robots by a kicking device which is strained by a wind-screen wiper motor and released by a solenoid. Furthermore we added movable ball steering flippers which can be turned to an upright position and back e.g. to allow better ball intercepting.

4 Perception

As in the last years' competitions, data from the laser range finders is used for self-localization and player-recognition [5,4,11]. Since we were basically satisfied with our technique for interpreting the laser scans we only consider minor modifications to it.

Data from the cameras is processed for ball recognition only. Since we count on a better vision hardware and intend to apply more specialized algorithms, we expect a more reliable and robust ball recognition. Furthermore, we plan to incorporate adaptive vision techniques to make our system robust against varying lighting conditions.

5 World Model

Each robot builds and maintains a local world model on the basis of its own sensor readings. The world model comprises the player's own position on the field, the ball position and the positions of other players as well as velocity and heading of every object. The local world model is extended by the results of a global fusion component that runs on an off-field computer and combines all estimates from the players. Observations from different robots with regard to the same object are fused using Kalman filtering. In addition, for the global ball position Markov localization is employed to exclude observations from sensor fusion which are most probably entirely wrong [12,2].

Furthermore we work on incorporating a model-based player recognition approach in order to improve the accuracy of the position estimates for other players, in particular the opponent goalie.

6 Communication

Our robots communicate via the WaveLan radio ethernet in order to build the global world model, to negotiate about role assignment and to send signals such as ”ready to receive a pass”.

7 Skills

For RoboCup 2000 we completely redesigned the skills of the field players in order to enable them to react in a more adequate way to a wider range of game situations [12]. Especially the ball-dribbling skill, which allows a player to conduct the ball around obstacles, and the ball-shooting skill, which considers rebound shots using the walls, improved the team performance considerably.

This year we particularly aim for a better handling of the ball in motion. We are confident that the better vison system and the faster robots now allow for intercepting the rolling ball, which in turn might serve as the basis for successful ball-passing.

Quit often a goal was scored against us because the goalkeeper was just turning away when the ball rolled towards it. We will therefore redesign the ball-searching and ball-tracking behavior of the goalkeeper exploiting the camera's pan-tilt capability.

8 Strategy and Tactics

Our action selection module [7] is based on extended behavior networks proposed by Dorer [3]. They are a revised and extended version of the behavior networks introduced by Maes [6] and can be viewed as a particular form of decision-theoretic planning.

The CS Freiburg players organize themselves in roles, namely *active*, *support* and *strategic*. While the active player always tries to get and play the ball, the supporting player attempts to assist by positioning itself appropriately. The strategic player always aims to occupy a good defensive position. Each player constantly calculates its utility to pursue a certain role and communicates the result to its teammates. Based on its own and the received utilities a player decides which role it wants to take. This approach is similar to the one taken by the *ART* team [1][1].

The target positions of the players are determined similar to the SPAR method of the *CMU* team in the small size league [9]. From the current situation observed by the robots a potential field is constructed which includes repulsive forces arising from opponent players and attracting ones from desirable positions, e.g. positions from where the ball is visible. Positions are then selected based on the robot's current role.

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[1] Note, however, that our approach was developed independently.