# FU-Fighters 2002 (Middle Size)

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## 1 Introduction

The RoboCup team of the Freie Universität Berlin has been a successful competitor in the Small Size league since 1999. In Seattle 2001, we won the Small Size Local Vision contest with a team of robots that featured an omnidirectional drive and an omnidirectional local vision system [4]. For RoboCup 2002, we decided to port our design to the Middle Size league. This has the advantage that we can include the computational resources needed for real time image analysis on board the robots.

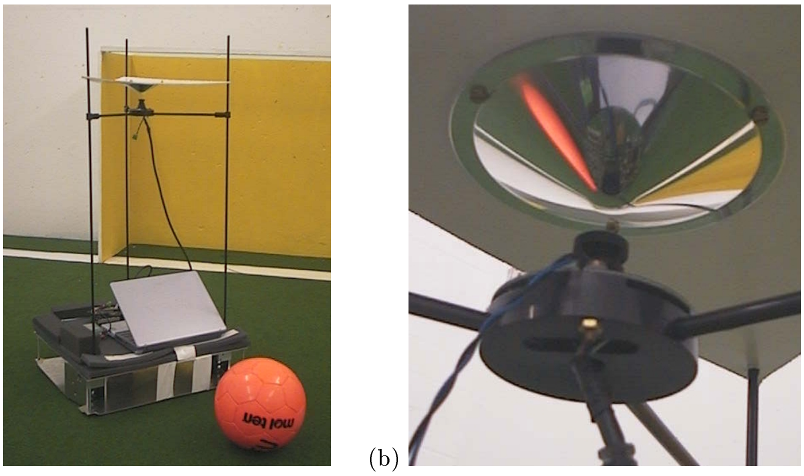
Since we are used to the relatively rapid and complex game situations in the Small Size league, our design goal was to create a team of robots that can play fast, with good control, and coordinated.

## 2 Mechanical and Electrical Design

Based on our experience with omnidirectional drives in the Small Size league, we decided to construct a robot base that contains three wheels that drive in the tangential direction and can be rolled in the orthogonal direction. This base can move in any direction and turn at the same time. The wheels are driven by motor gear combinations that have been extracted from battery powered drilling tools. They are designed for a top speed of 4m/s. To limit the energy needed for acceleration, we tried to keep the weight of the base as well as the payload low.

Electrical power is supplied by Ni-MH rechargeable batteries and switched by motor drivers that have a servo interface. This interface is connected to a microcontroller board that generates the desired pulse length. The board contains a Motorola HC12 chip and is described in [5]. The controller also reads infrared proximity sensors. The sensors are arranged in a ring around the robot and can detect nearby obstacles. If a collision would occur, the controller changes the robots movement vector to avoid the contact. The HC12-board also controls the operation of a kicking device.

For higher level behavior control and computer vision, a sub-notebook PC is located on top of the base. It is connected to the microcontroller via a RS-232 serial link. Further, it is connected by USB to two infrared optical flow detectors that sense the motion of the robot with respect to the carpet. On top of the robot a camera is mounted that looks trough a mirror in all directions around the robot. Figure 1 shows the robot design and a closeup of the camera-mirror combination. A Firewire (IEEE 1394) connection transfers the video stream from the camera to the notebook. The notebook also contains a wireless network interface that complies to the IEEE 802.11 standard.



(a) (b)

**Fig. 1.** Omnidirectional robot design: (a) total view showing omnidirectional base, notebook and camera mount; (b) detail of omnidirectional camera and mirror.

## 3 Computer Vision

The main sensor for the robots is an omnidirectional camera. It can provide images up to a resolution of $640 \times 480$ at a rate of 30fps. The images are transfered into the notebook's main memory by a 1394 camera driver in YUV color format.

Image analysis works in two modes: localization and tracking. For initialization and when tracking fails, a global image analysis is used to estimate the parameters of a world model, e.g. the robot's position and orientation as well as the positions of the ball and obstacles. This localization phase may take longer than 30ms since it is needed only rarely.

Since the world changes slowly relative to the frame rate, these parameters will not be very different in the next frame. Thus, we project the world model into the next captured image and inspect only parts of it to detect the deviations. These are used to update the model parameters. Such a tracking approach allows to interpret high resolution images at high frame rates without using much computing power. The tracking of the field, the ball, and obstacles is illustrated in Figure 2. More details about the omnidirectional vision system used 2001 in Seattle can be found in [3].

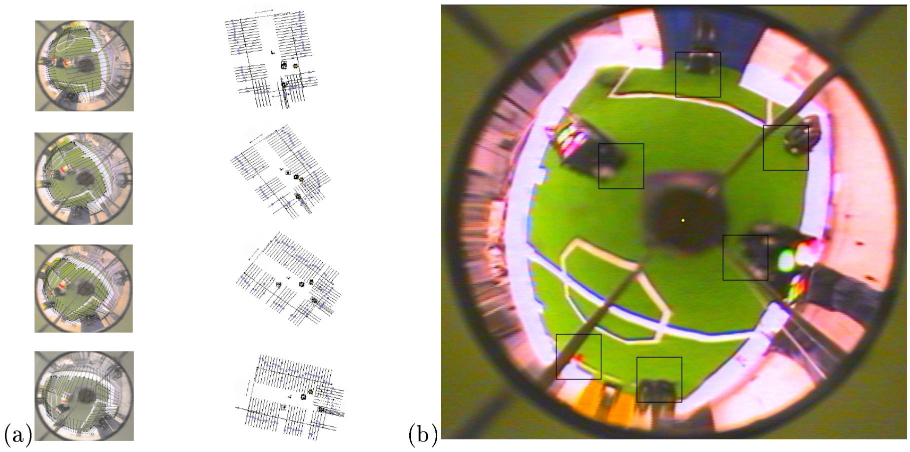


**Fig. 2.** Tracking of (a) the field while rotating; (b) ball and obstacles.

The computer vision module supplies the estimated world parameters to behavior control and to a global world model.

## 4 Hierarchical Reactive Behavior

We use a hierarchy of reactive behaviors to control the robots. Simple behaviors are arranged in layers that work on different time scales.

Fast primitive behaviors are implemented in the lower layers. On the lowest layer, motion control is done. Using the output of the infrared motion sensors, the three motors are driven such that the robot achieves a desired motion state, specified by translational and rotational velocities in a local coordinate system. This desired motion is determined by the next layer, that implements behaviors like taxis and obstacle avoidance.

In the middle layers, skills like approaching the ball, dribbling, and kicking it towards a target, are controlled. More complex, but slower behaviors are produced by the higher layers of the system. They include path planning and team cooperation. A more detailed description of our control architecture is given in [1, 2].

The path planner is realized using a grid based approach. Each grid cell represents the costs of moving through it. Obstacles and the goal box cause high costs. Also the initial robot velocity and the desired velocity at the target position cause costs. The optimal path is found using dynamic programming. It's start is communicated to lower levels of the behavior hierarchy as taxis target. More information on the path planner can be found in [5].

## 5 Communication and Team Play

The robots communicate via a wireless local network with a central station located outside the field. They send their local world model to the base. Here, the local views are merged in a probabilistic framework to produce a global view. The global estimation of the world's state is sent back to the robots. This fusion of local models has the effect that a robots knows the ball position even in a situation when it is occluded from it's point of view by another robot. Since communication with the central station causes some delay, the central station tries to predict the state of the world for the near future to cancel this effect.

In addition to the global world model, the central station also runs the team level of behavior control. Here, the actions of the individual players are coordinated. It is decided, which role is given to which robot. For instance, it is decided which robot takes the initiative and approaches the ball. These decisions are communicated to the robots and configure there the local behavior control. For the case that the wireless communication fails, each robot is free to act without global supervision according to its local view to the world.

## 6 Conclusion

For the Middle Size RoboCup competition 2002 we have developed a team of fast and lightweight robots that are capable of controlled and coordinated play. By accelerating the game, we hope to advance the state of the league.

## References

1. Behnke, S., Frötschl, B., Rojas, R., Ackers, P., Lindstrot, W., de Melo, M., Schebesch, A., Simon, M., Sprengel, M, Tenchio, M.: Using hierarchical dynamical systems to control reactive behavior. *In: Veloso, M., Pagello, E., Kitano, H. (eds): RoboCup-99: Robot Soccer World Cup III*, pp. 186-195, Springer, 2000.
2. Behnke, S., Rojas, R.: A Hierarchy of Reactive Behaviors Handles Complexity. *In: Hannebauer, M., Wendler, J., Pagello, E. (eds.): Balancing Reactivity and Social Deliberation in Multi-Agent Systems*, pp. 125-136, Springer, 2001.
3. v. Hundelshausen, F., Behnke, S., Rojas, R.: An Omnidirectional Vision System that finds and tracks color edges and blobs, In: Birk, A., Coradeschi, S., Tadokoro, S. (eds): RoboCup-01: Robot Soccer World Cup V, Springer, 2002.
4. Rojas, R., v. Hundelshausen, F., Behnke, S., Frötschl, B.: FU-Fighters Omni 2001 (Local Vision), In: Birk, A., Coradeschi, S., Tadokoro, S. (eds): RoboCup-01: Robot Soccer World Cup V, Springer, 2002.
5. Rojas, R., Behnke, S., Liers, A., Knipping, L.: FU-Fighters 2001 (Global Vision), In: Birk, A., Coradeschi, S., Tadokoro, S. (eds): RoboCup-01: Robot Soccer World Cup V, Springer, 2002.