# MuCows

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### 1 Introduction

The University of Melbourne entered the RoboCup contest for the first time in 2000, fielding teams in both the F180 and Sony Legged Leagues. This paper describes certain aspects of our F180 team: the MuCows.

The MuCows played three (official) matches in the course of RoboCup2000. The scores were as follows: won 14:0 against the 4 Stooges (University of Auckland, NZ); lost 0:7 against Big Red (Cornell, USA); lost 0:1 against CFA (UPMC, France). The score-line in the first match, against NZ, reflects the differences in the technology employed by the two teams. NZ was at a great disadvantage from the outset as a result of their decision to use local (on-board) rather than global (overhead) vision. While their robots had difficulty finding the ball, our robots had access to accurate global state information (obtained from an overhead camera). Consequently, this match was effectively a test of the MuCows' ability to score against an open goal. The second match, against Cornell, was a great deal more interesting. Cornell (who went on to win the competition), demonstrated three decisive technologies: effective dribbling, effective kicking and omni-directional drive. In contrast, while our robots were equipped with very similar dribbling and kicking mechanisms (see Section 7), they lacked the omnidirectional drive. Not only were the Cornell robots more maneuverable, they were able to use this maneuverability to enhance the effectiveness of their dribbling and kicking mechanisms. This match was effectively a test of our defense (somewhat weak) against Cornell's sustained attack. The final match, against UPMC, was by far the closest of the three matches. Both teams employed similar technology, resulting in a hard-fought match. Unfortunately (for us), UPMC was able to score a goal late in the second half using a clever 'spin-kick' technique. This technique allowed UPMC to attack the goal from low angles, making blocking extremely difficult.

The competition highlighted a number of strengths and weaknesses in our team. The strengths were: the robot chassis, which proved to be rugged and reliable; the vision system, which as quick to calibrate and very reliable; the communication system, which was by far the most capable system fielded by any team. On the other hand, our weaknesses included: poor player skills (the robots could not shoot straight); poor teamwork (the robots executed fixed roles and failed to exploit opportunities). In short, our team was strong on the engineering aspects of the problem (hardware, software architecture), but weak on the science aspects (AI, teamwork).

The remainder of this paper will focus on our team strengths; we will present a high-level overview of the robot hardware and software architectures, together will a somewhat more detailed look at the specific technologies of vision and communication. This paper is perhaps most useful to would-be RoboCup competitors as a 'cheat-sheet' on building a reliable hardware and software platform on which to base further development.

# 2 Team Development

Team Leader: Andrew Howard Team Members:

Jason Thomas, Thanh The Pham.

Lam Moc Truong, Kevin Phuoc Duy Nguyen

- University of Melbourne, Australia
- Undergraduate students (present a competition)

Andrew Peel, John Horvath, David Hornsby, Thomas Weichart

- University of Melbourne, Australia
- Technical support (present at competition)

Web page http://www.cs.mu.oz.au/robocup

### 3 Hardware Platform

We employ a fairly conventional F180 set-up, with both on-field and off-field components. On-field, we employ a set of five simple-but-sturdy robots. The robot are equipped with a differential drive system, odometry and battery sensing, a relatively powerful 8-bit RISC CPU and a spread-spectrum communications module. Very little computation is performed on the robots; they implement basic PID velocity control, but otherwise act as "remove controlled" vehicles. Off-field, we employ a single overhead camera and frame grabber, a cluster of three PCs, and a spread-spectrum communications module. The vast majority of the sensing and computation is carried out by the off-field components.

The communications technology employed by our team deserves particular attention, as it is one of the strengths of our team. The overwhelming majority of the competitors in the F180 league employ Radiometrix RPC transceiver modules. These modules are compact, low-power, cheap and easy to use; unfortunately, they will only transmit on two frequencies: 418 and 433MHz. This presents two difficulties: from an organizational standpoint, it implies that only two teams can be playing or practicing at any give time; from a reliability standpoint, it implies that one must expect significant interference (this is a shared band). After early experiments with these devices, we decided to invest some time in researching alternatives, and eventually located a multiple-channel spread-spectrum digital transceiver from Innomedia. This device operates at 2.4Ghz, has 12 channels (thus avoiding the frequency clash issue) and uses spread-spectrum technology (thus reducing the interference). We were able to manufacture an adapter board that makes these modules pin-and-protocol compatible with the

Radiometrix RPC modules, making the transition to these devices very straightforward. Cost is comparable to the RadioMetrix RPC modules, but with less latency, higher through-put (140kb/s vs 40kb/s) and better reliability. The devices are, however, somewhat larger and require more power. During the contest, we were one only a few teams not to experience radio interference problems.

### 4 Software Architecture

The MuCows software architecture is built around a set of modules that interact by passing messages. The message-passing mechanism is based on a publish/subscribe metaphor; any given module will *publish* some message types and *subscribe* to others. This design has a key advantage – since modules have no direct knowledge of each other, whole modules can be replaced without affecting the remainder of the system. Thus, for example, the system can be made to interact with either the physical robots or a simulation of the robots through the replacement of a single module. The message-passing mechanism also has the additional advantage that it facilitates the creation of distributed systems; during the contest, the total system was in fact distributed across three computers.

#### 5 World Model

We are able to construct a fairly complete description of the state of the world. The state description includes: the position and velocity of the ball; the position, orientation and velocity of our own robots; the position, orientation and velocity of the opposition robots. All of this information can be obtained more-or-less directly using raw data from the overhead camera, together with post-processing through a set of Kalman filters. The basic algorithm is as follows:

- Perform a basic color segmentation on the image pixels. Each pixel is determined to be part of either a robot, the ball or the background.
- Apply a median filter to the segmented image. This removes removes most of the pixel noise.
- Cluster the remaining pixels into blobs. Each blob is determined to be either one of our robots, one of the opposition robots, or the ball.
- Identify blobs. For our own robots, use pattern matching on the surrounding pixels to determine the identity of the robot (each robot has a unique black-and-white pattern). For opposition robots, use a track-continuation algorithm to assign an arbitrary identity to each robot.
- Feed the identity and location of the blobs into a set of Kalman filters to extract a filtered estimate of each object's pose and velocity.

In addition to determining the state of the world, we also make predictions about future states. For the opposition robots and the ball, we use a Kalman filter to generate the prediction. For our own robots, we allow each robot to advertise its *intentions*; i.e. its planned trajectory. Using these predictions, we are able to implement behaviors which are both dynamic and cooperative, such as passing, interception and blocking. See [1] for a full description of this approach.

## 6 Strategy

MuCows team strategy is implemented through the concept of set-plays, in which each robot is assigned a particular role (such as striker, blocker, etc). The set-plays include the concepts of possession, passing, blocking and looking for openings, and can express quite complex team interactions. Unfortunately, they do not provide a mechanism for role re-assignment. During the contest, it quickly became evident that this was a major deficiency: robots executing fixed patterns of behavior would fail to exploit emergent opportunities. For example, if a robot was assigned the role of blocker, it would not attempt to score goals even when a scoring opportunity presented itself. Clearly, a much more flexible and opportunistic approach is required.

# 7 Special Team Features

The MuCows is one to two teams (Big Red, from Cornell being the other) to introduce dribbling mechanisms into the contest. Our mechanism is a rapidly rotating roller that applies significant back-spin to the ball. As a consequence, the robot is able to 'kick the ball to itself'. In pre-contest experiments, we were able to achieve a very high degree of ball control: dribbling the ball all the way from the back line to the goal, for example. Under actual game conditions, however, we were unable to fully capitalize on this ability. The rules on contact are such that opposition robots could easily strip an attacking player of possession. Interestingly, Cornell was able to make much better use of their roller due to the superior maneuverability afforded by their omni-directional drive mechanism.

### 8 Conclusion

Analysis of the 2000 contest has revealed three major areas that need to be addressed: increased mobility through the construction of omni-directional drives, improved skills through better tuning of low-level controllers, and improved game play through the use of more flexible approaches to teamwork. Given the demonstrated robustness of our basic hardware and software architectures, we feel we are in an excellent position to address these issues and return the the contest in 2001 with a much improved team.

#### References

[1] Andrew Howard, Alan Blair, Dariusz Walter, and Ed Kazmierczak. Motion control for fast mobile robots: a trajectory-based approach. In *Australian Conference on Robotics and Automation*. Australian Robotics and Automation Association, 2000.