# Review of Mobile Robot Competitions

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## Abstract

A number of international competitions for mobile robots have been created and conducted during the last 20 years. This article discusses three of the arguably most prominent event series and their impact on mobile robot research, teaching, and media recognition. We will highlight scope, rules, robot designs and robot evolution over the years for the Micromouse Contest, AAAI Mobile Robot Competition and RoboCup and discuss their contributions to mobile robot research.

## 1 Introduction

Mobile robot demonstrations always have a big impact on the media, which of course in many cases is directly linked to the availability of funding from university and other sources. More practically, robot competitions provide both a goal and an objective measure for performance. This should not be underestimated in a research area still looking for major industrial applications.

Mobile robot competitions create student interest and inspire them to work dedicatedly on their projects. The practical solutions they find for all the small problems on their way will teach them more skills than a lecture ever can.

But is it worth to invest much time and money in "just a student competition"? Can an actual research benefit be expected from these events or is it just to attract media attention?

## 2 Micromouse Contest

*"The stage was set. A crowd of spectators, mainly engineers, were there. So were reporters from the Wall Street Journal, the New York Times, other publications, and television. All waited in expectancy as Spectrum's Mystery Mouse Maze was unveiled. Then the color television cameras of CBS and NBC began to roll; the moment would be recreated that evening for viewers of the Walter Cronkite and John Chancellor-David Brinkley news shows"* [Allan 1979].

This report from the first "Amazing Micro-Mouse Maze Contest" demonstrates the enormous media interest in the first mobile robot competition in New York in 1977. The academic response was also overwhelming. Over 6000 entries followed the announcement of Don Christiansen [Christiansen 1977], who originally suggested the contest.

The task is for a robot mouse to drive from start to goal in the fastest time. Rules changed somewhat over time, in order to allow exploring the whole maze and then compute the shortest path, while also counting exploration time at a reduced factor.

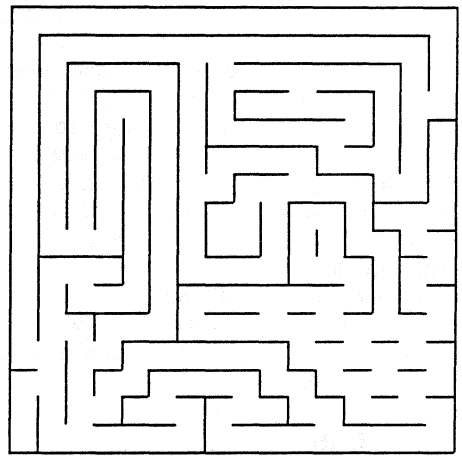

Figure 1: Maze from micromouse contest in London 1986, displayed by EyeSim simulator www.ee.uwa.edu.au/~braunl/eyebot/doc

The first mice constructed were rather simple - some of them contained not even a microprocessor as controller, but were simple "wall huggers" which would find the goal by always following the left (or the right) wall. Some of these scored even higher than some of the "intelligent" mice, which were mechanically slower.

John Billingsley [Billingsley 1982] made the micromouse contest popular in Europe, while a real micromouse craze was going around the world. Virtually all the robotics labs I know were building micromice in one form or another. All of a sudden, people had a goal and could share ideas with a large number of colleagues who were working on exactly the same problem.

Micromouse technology did evolve quite a bit over time, as did the running time. A typical sensor arrangement was using three sensors to detect any walls in front, to the left, and to the right of the mouse. Early mice used simple micro switches as touch sensors, while later on sonar, infrared, or even optical sensors [Hinkel 1987] became popular.

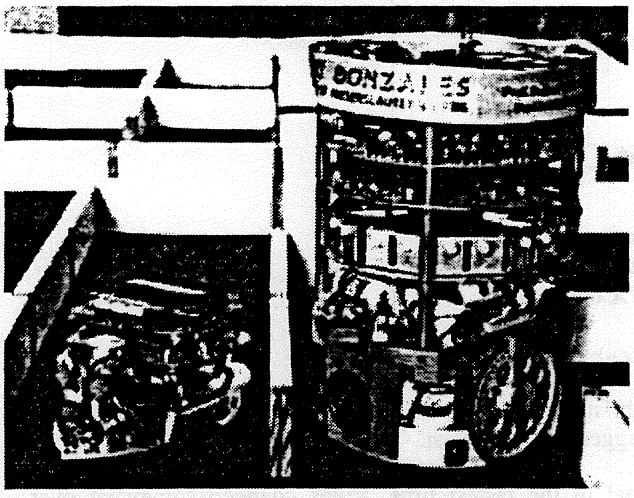

Figure 2: Two generations of Micromice from Univ. Kaiserslautern (photo Ralf Hinkel and Ewald von Puttkamer)

While the mouse size is restricted by the maze's wall distance, smaller and especially lighter mice have the advantage of higher acceleration/deceleration and therefore higher speed. Even smaller mice became able to drive in a straight diagonal line instead of going through a sequence of left/right turns, which exist in most mazes.

One of today's fastest mice comes from the Univ. of Queensland, designed by Gordon Wyeth (there are still micromouse competitions held in 1999), using three extended arms with several infrared sensors each for reliable wall distance measurement. By and large, it looks as if the micromouse problem has been solved, with the only possible improvement being on the mechanics side, but not in electronics, sensors or even software.

## 3 AAAI Mobile Robot Competition

In the end of the 1980s, the micromouse contest had outlived itself and the robotics research community was losing interest. The problem was solved and did not provide any further challenges. Around that time David Kortenkamp initiated the AAAI Mobile Robot Competition [Kortenkamp et al. 1993]. The first event was held at AAAI 1992 in San Jose, California, where ten robots competed in three events. These were:

- "roaming [a 22m × 22m] area and avoiding obstacles (cardboard boxes) and wandering judges"
- "searching for 10 distinctive objects [three-inch diameter poles] and then visiting each of the objects
- "timed race to three of the objects found [in previous task] and then back home"

While the AAAI competitions created new challenges, they were not as media friendly as the micromice - basically because most of these tasks took about 20 min. to complete and the audience could not judge what processes and state changes were going on "inside the robots".

New tasks have been introduced over the years. Some competition events were kept over several years and only slightly modified, while other events were modified earlier. The idea was to always present a new challenge rather then leave one event for too long, so it would not get solved easily. For AAAI 1996 in Portland, Oregon, the tasks were:

- "call a meeting"
  robots have to act as messengers by solving navigation tasks around a (mock) office environment
- "clean up the tennis court"
  robots have to collect tennis balls from a rectangular area and bring them back into a pen

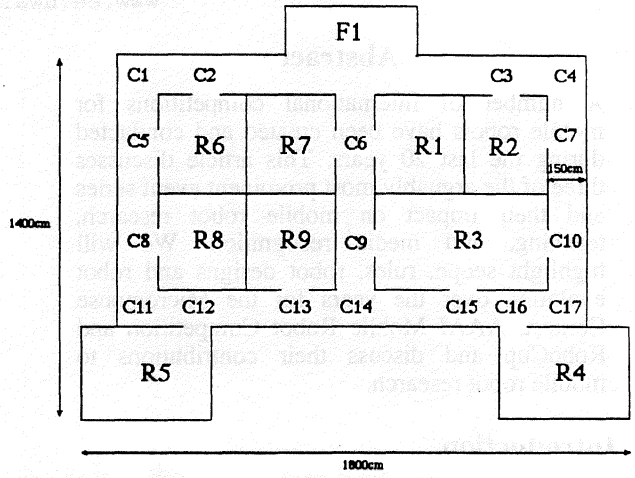


Figure 3: Sample area for "call a meeting" task (from Kortenkamp's web site 1996)

Although the office navigation seems to have a remote resemblance to the micromouse maze, it is quite different. The floor plan is known to the robots before they start, as well as the rooms they have to visit. So it comes down to reliable driving without hitting a wall and correct recognition of (open) doors and hallways. If this sounds almost trivial - it is not, since it takes place in a near-real environment with the typical problems of lighting, (sensor) reflections, etc.

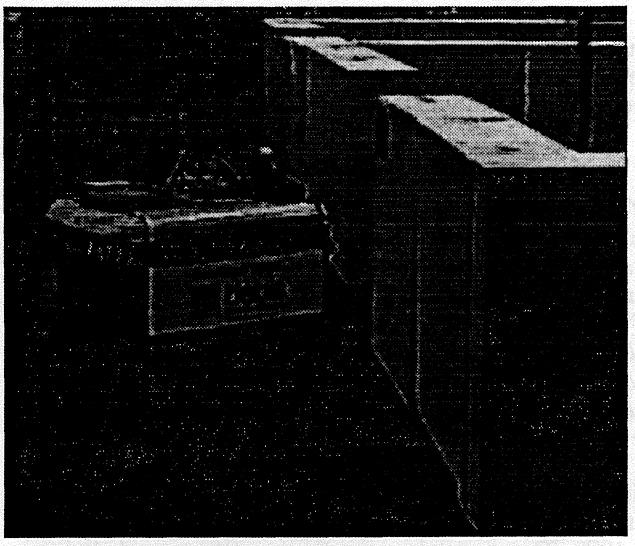

Figure 4: Office navigation robot from Univ. Stuttgart, IPVR

While "call a meeting" could be solved by using sonar or laser range sensors, "clean up the tennis court" required the use of image processing in order to detect and track the tennis balls. "Squiggle balls" (balls with a motor inside to make them follow unpredictable paths) were added as an extra difficulty. Traditional planner-based programs can be used to solve the office navigation task. The ball collection task on the other hand allows a choice of either planning or behaviour-based approaches. Newton Labs won this event in 1996 with a behaviour-based approach. The robot would just search for a yellow tennis ball with its color camera, then rush towards it, grab it, and then search for the pen area (marked by a blue bar) to return the ball. It did not make use of cartesian coordinates and had no internal model of its position or orientation, although it would have been advantageous to do so. Other approaches, like Univ. Stuttgart [Bräunl et al. 1996], used a sweeping pattern or area covering approach, employing vision to catch individual stray balls.

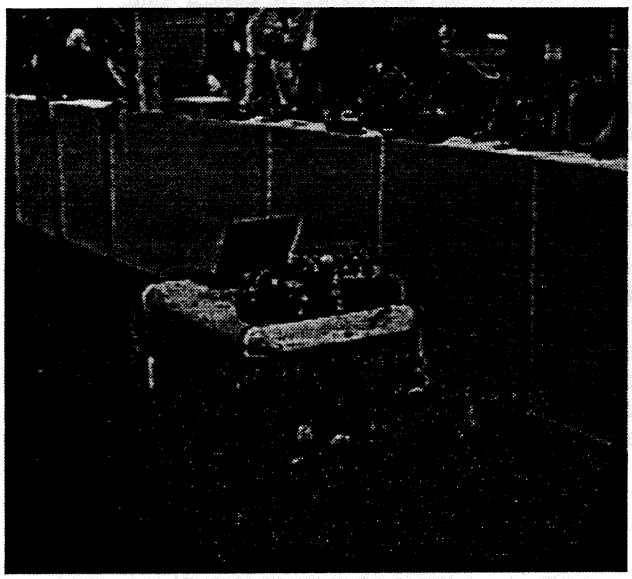

Figure 5: Ball collecting robot from Univ. Stuttgart, IPVR

## 4 RoboCup

*"The Robot World Cup Initiative (RoboCup) is an attempt to foster AI and intelligent robotics research by providing a standard problem where wide range of technologies can be integrated and examined. For this purpose, RoboCup chose to use soccer game, and organize RoboCup: The Robot World Cup Soccer Games and Conferences. In order for a robot team to actually perform a soccer game, various technologies must be incorporated including: design principles of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning, robotics, and sensor-fusion. RoboCup is a task for a team of multiple fast-moving robots under a dynamic environment. RoboCup also offers a software platform for research on the software aspects of RoboCup."* (from the RoboCup web site `www.robocup.org`)

So robot soccer brings mobile robots to the spectator sport. Huge media interest was the result after Hiroaki Kitano created this competition in 1997 [Kitano et al. 1997]. The competition actually comprises three leagues at the moment:

- Small size league (max. 180cm$^2$ robot floor area)
- Medium size league (max. 2000cm$^2$ robot floor area)
- Simulator league

A planned large size league has been dropped, while legged robot soccer leagues and commentator leagues are currently being discussed.

Robot soccer teams play five-a-side soccer with rules that are freely adapted from FIFA soccer. Since there is a boundary around the playing field in both "real" robot events, the game is actually closer to ice hockey. The big challenge is now not only that reliable image processing has to be performed in real time, but also that the own team of five robots/actors has to be organised. In addition, there is an opponent team which will change the environment (e.g. kick the ball) and thereby render one's own action plans useless if one is too slow.

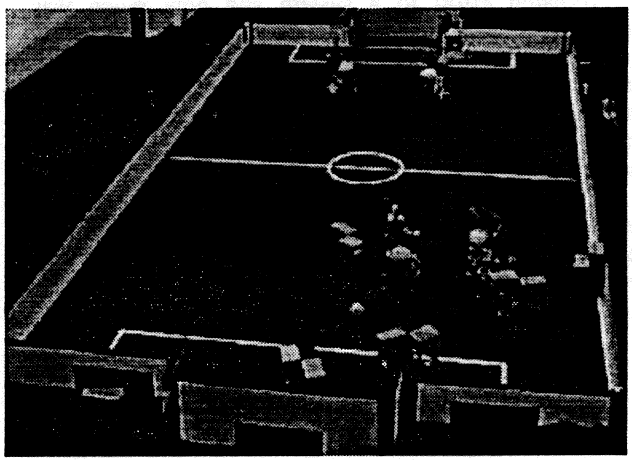

Figure 6: Robot Soccer Team CIIPS Glory UWA vs. Singapore

The small size league plays on a ping-pong-size field. It allows the use of external sensors, especially the use of an overhead camera, which allows absolute positioning of robots (own and opponent), ball and goals. Most of the teams so far follow this approach, which requires a wireless transmission from the image processing workstation to the robots. This led to the development of remote controlled units (one team actually used remote controlled toy cars) rather than mobile robots with local sensors. Most teams have no sensors at all on the robots, and communication is a one-way broadcast from the workstation to the robots. An exception is here the robot soccer team from UWA [Bräunl and Graf 1998], which uses local vision and on-board computation without communication.

The medium size league does not allow global vision, so the participating robots are required to have local sensors and local intelligence (however, remote control from powerful workstations is still allowed). Many teams use off-the-shelf mobile robots driven by laptop computers. This makes it a costly exercise, which not all interested institutes are capable of funding or willing to fund. In addition, the large field size of up to 10m × 7m makes it hard for many teams to find appropriate practice/lab space.

## 5 Research Contributions

One of the frequent disappointments of robot competitions is that enormous research efforts are being reduced to performance in a particular event and cannot be appreciated adequately. Adapting from the home lab environment to the competition environment turns out to be quite tricky, and many programs are not as robust as their authors had hoped.

On the other hand, the actual competitions are only one part of the event. Most competitions are embedded in conferences and encourage participants to present the research behind their competition entry, giving them the right forum to discuss related ideas.

At first glance competitions seem to be an objective measure for good research, but this is certainly not true. Several aspects have to be taken into account. Are human judges involved, does a team have a "home advantage" (e.g. the competition environment being their development/test environment), and how much is a team's own research effort to a system and how much was bought-in technology? Several mobile robot companies already offer specialised products for RoboCup or AAAI competitions, including both hardware *and* software. So money can make quite a difference here, which makes it almost impossible to evaluate and honour the actual research contribution.

Most mobile robot competitions involve interesting research problems which could be studied in their own right. The following (non-exhaustive) list mentions just a few of them:

- robot soccer
  - multi-robot / multi-agent scenarios
  - cooperative work
  - communication
  - real time image tracking
  - object identification
  - sensor fusion
  - planning
- office navigation
  - planning
  - robust (sonar) sensor processing
  - obstacle avoidance
  - human-robot interaction
- ball collection
  - mechanics for ball collection
  - path planning
  - robust sensor processing
  - real time image tracking

I believe that all mobile robot competitions mentioned in this paper undoubtedly brought progress to the field by inspiring the people who worked on it and by continuously pushing the limits of what is possible. Progress has been made through the competitions in mechanics, electronics, and algorithms. We have already seen technology changes for the micromice. Starting with tactile sensors, improving with sonar sensors, and finally reaching a near perfect state with optical line sensors and arrays of infrared sensors.

It is interesting to see that smaller robots tend to perform better. Not only because of obvious path advantages as for a micromouse being able to drive diagonally, but e.g. also for both AAAI'96 competition tasks. Smaller robots have less mass and can accelerate/react faster. However, they have the disadvantage of much tighter payload and battery restrictions, which severely limit the sensor and computing equipment that can be carried (unless wireless transmissions are allowed).

The simpler vision systems used for RoboCup are capable of performing image processing at a rate of two frames per second. These teams cannot compete against realtime vision systems with the PAL frequency of 25 fps (50/2), while some teams reach image processing *and* command update frequencies of up to 60 fps.

Micromouse and AAAI (so far) have been rather static problems, which were basically "solved" at some stage. RoboCup on the other hand means playing an opponent, which will evolve as well over the years, so it will hopefully remain interesting for quite a while.

There are a number of other mobile robot competitions not mentioned here and a number of new ideas are being discussed. However, it is hard to design an "optimal" event, which covers all currently valid research areas, discourages industrial solutions and is still fun to the students.

## Conclusion

Mobile robot competitions are a big opportunity for robotics research. They create media interest and may even generate additional funds from various sources. Competitions create student interest and inspire them to work dedicatedly on their projects. The practical solutions students find for all the small problems on their way will teach them more skills than a lecture ever can.

So it may actually be a good idea to participate in a robot competition, provided that the individual research goals are covered by the particular event. It can be seen as a useful "umbrella", which provides a meaningful application to a number of more or less related robotics research topics.

However, we must be careful not to confuse a competition with research. The objective for competitions must remain to interest students in a particular research area, to foster or initiate research for particular components in mechanics, electronics or software, and to build a reliably working solution to a given problem. A competition must not be *"l'art pour l'art"*, it can only be part of a larger, well organised research program.

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