

# Ten Years of the AAAI Mobile Robot Competition and Exhibition

## Looking Back and to the Future

*Tucker Balch and Holly A. Yanco*

■ Summer 2001 marked the tenth AAAI Mobile Robot Competition and Exhibition. A decade of contests and exhibitions have inspired innovation and research in AI robotics. Here we look back at the origins of the contest and how it evolved. We also reflect on how the contest has served as an arena for important debates in the AI and robotics communities. The article closes with a speculative look forward to the next decade of AAAI robot competitions.

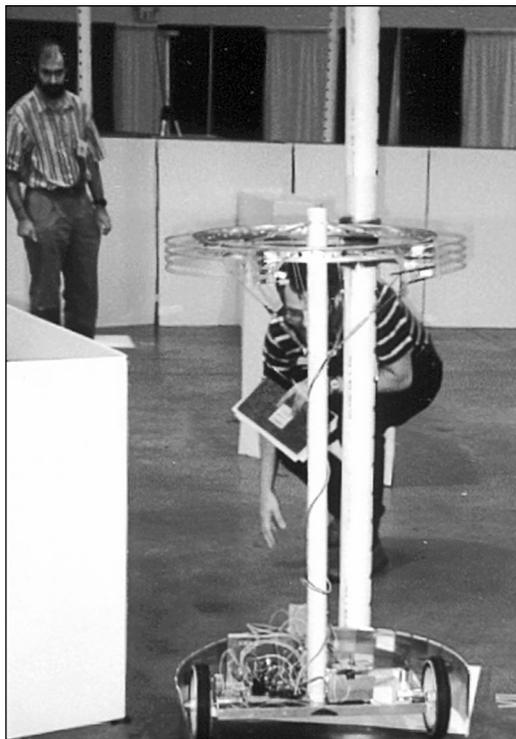
“This won’t be a slick, polished competition. There will be a certain amount of chaos, but I can guarantee there will be a lot of excitement and enthusiasm.”

—Tom Dean, 1992

In 1992, Tom Dean and Pete Bonasso convinced the American Association for Artificial Intelligence (AAAI) to host a robot competition at the National Conference on AI; the AAAI Mobile Robot Competition and Exhibition was born. The event has endured to become the oldest AI-centric robotics competition in the world. As we near the end of our first decade, it seems worthwhile to reflect on what the origins of the event were, how it has evolved, and where it is headed.

Pete Bonasso recalls that the entertainment industry had laid some of the groundwork for the contest by building expectations and excitement about robots in many people’s imaginations. Characters such as Star Trek’s COMMANDER DATA and BISHOP, the “artificial person” in James Cameron’s *Aliens*, made us all think about what might be possible. The concrete idea for a competition took root after a panel at AAAI-1991 on household robots. “Neats and scruffies alike were mesmerized by the animal-like responses of the robots demonstrated there,” says Bonasso. “At the end of that panel, a bunch of us got with Tom to talk up the idea of a competition.”<sup>1</sup>

Then-president of the AAAI, Patrick Hayes, hoped the contest would highlight the “cognitive possibilities for mobile robots” and demonstrate “the long-standing symbiotic relationship between AI and robots” (Dean and Bonasso 1993). Of course, some felt there is more than a symbiosis between AI and robotics; that there could be no intelligence without embodiment (Brooks 1991). Over the years, the event and *AI Magazine* have served as a venue for this and several other intellectual debates, including sensing versus modeling, color-based versus shape-based object recognition, and reactive control versus symbolic planning for robot navigation (Balch et al. 1995; Buhmann et al. 1995; Dudek 1998; Firby



*Figure 1. SCARECROW, the Robot That Didn't Have a Brain, in the 1992 Competition.*

et al. 1996; Mason 1993; Miller 1993; and Sargent et al. 1997).

Toward the end of the 1980s, the apparently stalled progress of symbolic AI for robot control, contrasted with Brooks's and Arkin's successful reactive strategies, seemed to foreshadow a dominance of behavior-based approaches in the 1990s. In 1992, David Miller and his son, Jacob Milstein, made the point that symbolic representation might not always be necessary with their stark robot SCARECROW (figure 1). SCARECROW was controlled by a simple circuit of wires and relays (no computer controller). Although SCARECROW didn't win the competition, it did well, making some competitors quite nervous. Miller relishes the memory: "For at least five years after '92, I received e-mail and letters from researchers around the world asking for more details about SCARECROW's spatial representation and planning system. I would tell them its spatial representation system was 100-percent accurate and full fidelity ... the representation was quite large and was stored mostly off board the robot."

In fact, robots following reactive strategies often claimed the winner's circle (for example, Balch [1998]; Balch et al. [1995]). However, in other years, robots that relied on representation and planning stole top honors (for example, Buhmann et al. [1995]). The end of a

decade of competitions has seen a mellowing of the "religious" fervor on these issues as well as a realization among many that reactivity, planning, and representation will all play a role in the successful robots of the new millennium.

## Evolution

The contest immediately took on two important but apparently conflicting roles: First, it provided a target for research in AI and robotics; in Pete Bonasso's words, the event was cast "in the spirit of trying to develop as animate, responsive, and intelligent robot behavior as possible" (Dean and Bonasso 1993). Second, the contest provided a venue where people could demonstrate their work to the AI community.

Contest organizers faced the challenge of devising compelling problems worthy of world-class research (and the funding that goes with it) while balancing risk. The risk arises from the danger of setting the bar so high that no robot can complete the task. In the worst case, critics might interpret the failure of robots to complete the task as a systemic failure of AI robotics itself (Konolige 1997). The contest chairs have wrestled with these issues ever since. The competition's evolution reflects the organizers' efforts to keep the bar at the right level and provide relevant contest events that inspire and drive research.

For the first contest, Bonasso and Dean designed a competition with progressively more challenging trials. The contest centered on a task where the robots were expected to explore a large arena containing easily detected obstacles along with conspicuously marked objects to be located by the robots. Initial trials were conducted behind closed doors before the general public was admitted to the competition hall. Thus, the judges were able to assess the capabilities of the robots so they could tailor the final, public, trials for success. What a success it was—the 1992 competition was a big hit that ensured a place for the competition in subsequent conferences.

The competition grew to include multiple events because some researchers found one task or the other a better match for their funded research. Since this time, the robot competition has included about three problems every year (sometimes four, sometimes two). Over the three years spanning 1993 to 1995, some form of navigation task was maintained, along with a simple manipulation task. The complexity of the competition tasks, however, was kept at about the same level as the first contest.

Another aspect of the contest that has evolved over the years bears mentioning. The types of participants have changed over the years. In the early 1990s, a large portion of the competitors came from research universities such as Carnegie Mellon University (CMU), Stanford University, Georgia Institute of Technology, and the Massachusetts Institute of Technology. The entries from these universities often reflected the research of Ph.D. students and their advisers. In the mid to late 1990s, the mix of participants evolved to include a larger proportion of undergraduates from a broader selection of universities, including teaching colleges such as Swarthmore. This trend probably reflects the pervasiveness and accessibility of AI and robotics technologies. Recently, with the addition of new events, we are seeing research universities return to the competition.

“Where is the science?”—Tom Dean, 1994

“The science is what you do [back at the lab but] throw away the night before the competition.”—Jim Firby, 1994

The robots were providing an exciting show, but the researchers were still struggling to build robust systems that would convincingly complete the competition tasks (Simmons 1995). According to Tom Dean, one consequence of promoting such competitions, and their collocation with scientific conferences, is that the organizers and participants were constantly asked to explain the science under the hood, by peers, fellow conference attendees, the powers that sponsor such events (Defense Advanced Research Projects Agency, National Science Foundation, National Aeronautics and Space Administration, AAI, International Joint Conferences on Artificial Intelligence), and the press. “Indeed,” Dean says, “I was often placed in the position of ‘spinning’ comments made by participants that were picked up by the press to the effect that the real competitive advantage was a result of finessing tough problems, taking advantage of loopholes in the rules, and last minute hacks.”<sup>2</sup> Consequently, Dean took it on himself to play devil’s advocate and challenge the community to explain their contributions to science, engineering, and society. With regard to Firby’s quip, Dean said, “I’m sure that elegance suffered in the dark dawn prior to the final rounds of several competitions ... but Jim’s achievements were still due in large part to a deep understanding of very basic principles and years of hard-won experience cached out in well-designed systems.”<sup>3</sup>

Then, in 1995, the community reached an important milestone. According to David

Miller, that year’s organizer, “All the robots that competed in the events accomplished the tasks” (Hinckle, Kortenkamp, and Miller 1996). The successes of 1995 were enabled by corresponding research progress in the technology areas the contest was pushing, including the overcoming of ultrasonic sensor noise for navigation, the building of maps from noisy range sensors, real-time vision, and planning in a more or less structured environment.

The year 1996 marked a move to more dynamic and unstructured tasks (Kortenkamp, Nourbakhsh, and Hinkle 1997). The Tennis Court Cleanup task required robots to collect numerous tennis balls strewn about the arena and deposit them in a bin. The problem was further complicated by the addition of battery-powered, quickly moving “squiggle balls” that also had to be captured and delivered to a bin. One of the competitors, M1 from Newton Labs (figure 2), was able to chase a squiggle ball down and capture it. This competition was challenging and visually appealing as well. It also brought the reactive versus deliberative control debate to the fore; of the two top entries, M1 from Newton Labs was purely reactive, and JEEVES from CMU used symbolic reasoning.

Others outside the community were taking note of the competition’s success. Pete Bonasso recalls, “Some of my favorite recollections were seeing people like Ian Horswill, Maja Mataric, and Jon Connell having to patiently explain to CNN and other press reps that there really was no one behind the curtain.”<sup>4</sup> In 1996, the PBS television show *Scientific American Frontiers* asked if it could visit and tape the contest. The show’s host, Alan Alda, attended the competition in Portland, Oregon, and spent many hours observing and asking questions with his camera crew. The resulting program presented AI robotics in a very positive light.

By 1997, the robots were reliable enough that another research challenge could be added. The Hors d’Oeuvres, Anyone? event debuted in that year’s competition. The general idea was to have robots serve food to attendees at the conference’s banquet. This competition would drive research in manipulation; navigation in dynamic environments (for example, crowds of people); and, most notably, human-robot interaction. Because evaluation for scoring included an audience vote component, robots were rewarded for compelling interaction with people.

In addition to motivating research within the AAI community, the competition has had a strong impact on AI robotics research outside the competition arena. Two of the most visible

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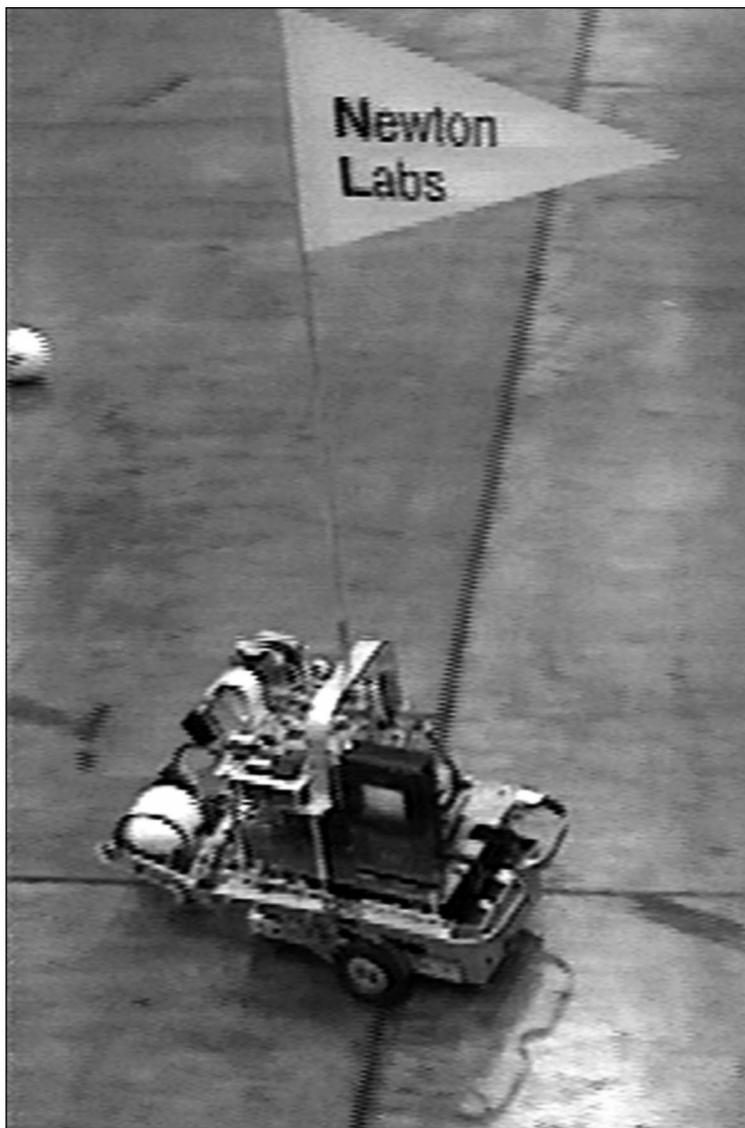


Figure 2. *Tennis Anyone?* Newton Labs' Home-Built Entry, M1, in the 1996 Clean Up the Tennis Court Event.

Newton Labs tied with JEEVES from Carnegie Mellon for first place in the event.

examples include the tour-guide robots developed by Illah Nourbakhsh's group and Sebastian Thrun's group (Thrun et al. 2000; Nourbakhsh et al. 1999). According to Thrun, "our tour-guide work was clearly strongly motivated by similar tasks in the mobile robot competition—in fact, without the competition, we would never have had the resources to do the museum tour-guide work."<sup>5</sup> Research in robotic rescue is another example. The AAAI Mobile Robot Competition hosted rescue competitions in 2000 and 2001 (Schultz 2001). Some of the same robots that participated in these events were used to explore the rubble at the World Trade Center site in September 2001.<sup>6</sup>

Variations on maze-navigation problems

(for example, the Office Delivery task) played a prominent role in the robot competition from the first contest through 1998. In 1999, however, the organizers deemed this problem solved and dropped it from the competition. At about the same time, some felt the competition had drifted from its original objective of showcasing and driving AI robotics research. It seemed that robots participating (and winning) had shifted from "state of the research" to "state of the art." In other words, the competitors were building their robots by integrating proven technologies; they weren't being forced to develop new technology. At the same time, graduate student teams demonstrating their thesis research were being supplanted by undergraduate students demonstrating their engineering skills.

These observations led to the development of a new event, the Mobile Robot Challenge. The intent of this event is to set the bar again at an appropriate level to draw cutting-edge research back to the contest. The challenge task is to develop a robot that can attend the National Conference on AI and present a talk about itself. Components of the problem include human-robot interaction, navigation in dynamic environments with and without a map, and accepting and scheduling of prioritized subtasks (for example, "please take this paper to the registration desk"). To date, the challenge has drawn only a few participants in comparison to the other events, but there are indications participation will increase for 2002.

Perhaps the most exciting recent change in the Robot Competition was the addition in 2000 of a Robot Rescue event. The task for robots in this event is to explore an arena that simulates a postearthquake environment for surviving humans. The rather sizable arena for this event was designed by Adam Jacoff and his team at the National Institute of Standards and Technology. The relevance of research in this area was brought home by the events of September 11, 2001. We expect substantial growth in this event over the next few years.

## The Exhibition

Since the first year of the event, the exhibition has been a forum for robotics demonstrations that fall outside the year's specified competition tasks. In the early years, when most of the competition tasks involved solving indoor navigation, people interested in other areas of robotics research found a place to bring their work. The first year, the event was actually called the AAAI Robot Exhibition and Competition, putting the exhibition of robots ahead

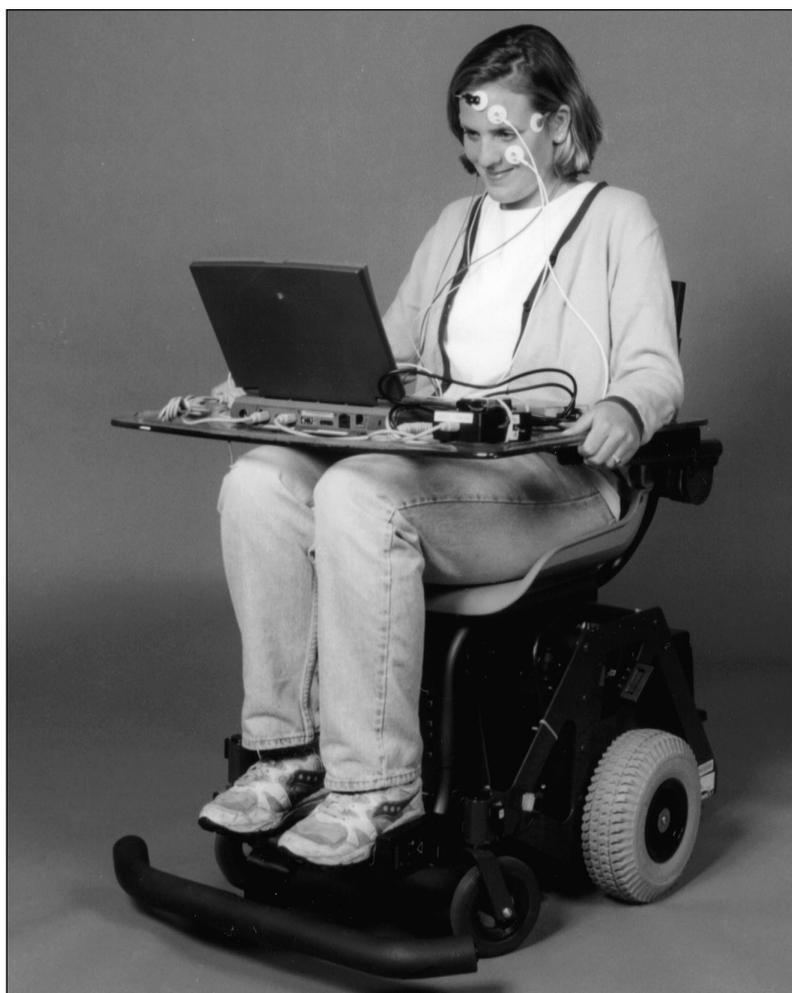
of the competitive aspects (Dean and Bonasso 1995).

Most frequently, the exhibitions have been given by graduate students, who bring their latest work to the event. In the first year, the exhibitors jumped into the ring whenever the competition wasn't going on; in later years, the exhibition has had rings of its own for demonstrations. The program has expanded over the years to include posters and video loops as well as live demonstrations, allowing people with nontraveling robots to participate. In 1997, the event gained its own chair, resulting in larger exhibitions.

The wide variety of systems that have been demonstrated in the past include robotic wheelchairs (figure 3), robotic sculptures, one-legged hopping robots, tubelike rolling robots, "dramatic robots," prototypes for Mars rovers, and humanoid robots as well as the more typical looking research robots. The exhibition has served as a forum for researchers to give demonstrations of their latest work, sharing research more quickly with the community. The spirit of open discussion of the research is present in all the events and is further encouraged at the Robot Workshop held at the end of the competition and exhibition.

A great deal of cutting-edge research has been presented at the exhibition, including the following systems: The first exhibition in 1992 was the site for the first demonstration of robots that learned languages for communication (Yanco and Stein 1993). In 1994, the exhibition was host to the first 1000-pound autonomous hovercraft from the University of Maryland. In 1995, Dave Miller's enthusiasm resulted in the demonstration of several robotic wheelchair systems in Montreal. To add a small bit of competition to this exhibition, the wheelchairs competed in a "doorway limbo." At the exhibition in 1997, Robin Murphy demonstrated her lab's research on robotics for urban search and rescue (which then debuted as a competition in 2000). Also in 1997, speech and gesture recognition for human-robot interaction were demonstrated on COYOTE (figure 4) from the Naval Research Laboratories (Perzanowski, Adams, and Schultz 1998). In 1998, Kurt Konolige (1997) demonstrated his SMALL VISION SYSTEM, a small, compact stereo head.

At the 2001 exhibition, the Nils Nilsson Prize for Integrating AI Technologies was awarded to an exhibition participant: CEREBUS from Northwestern University. CEREBUS gave an interactive talk about itself to interested passersby. This talk was the hit of the Robot Workshop that followed the Robot Competition and Exhibition. (See the article by Adams



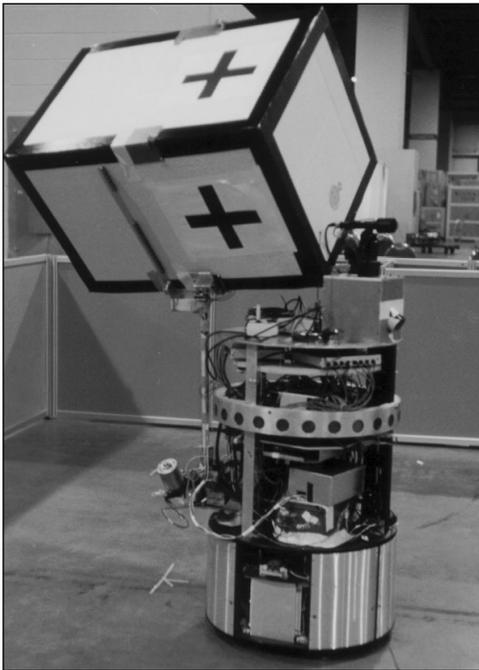
*Figure 3. The First Robotic Wheelchair Commanded by an Eye-Tracking Device, Shown at the 1997 Exhibition: WHEELSLEY from MIT with EAGLEYES from Boston College.*

and Verma, also in this issue, for further information on the research behind CEREBUS.)

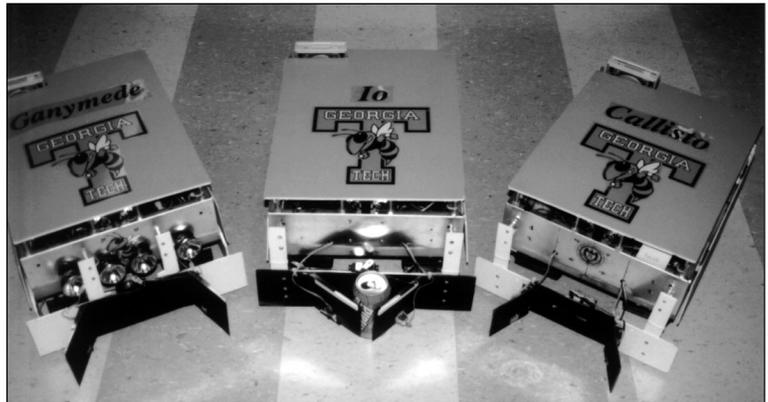
## The 2001 Competition

The Tenth Annual AAAI Mobile Robot Competition and Exhibition was held at the Seventeenth International Joint Conference on Artificial Intelligence (IJCAI-2001) in Seattle, Washington. The events included two competitions—Hors d'Oeuvres, Anyone? and Robot Rescue (held in conjunction with RoboCup-2001)—and a well-attended exhibition. We also welcomed the National Botball Tournament again this year in the AAAI exhibition hall, even experiencing cross-over when a high school student demonstrated a snake robot called SLITHER that he had built with his father.

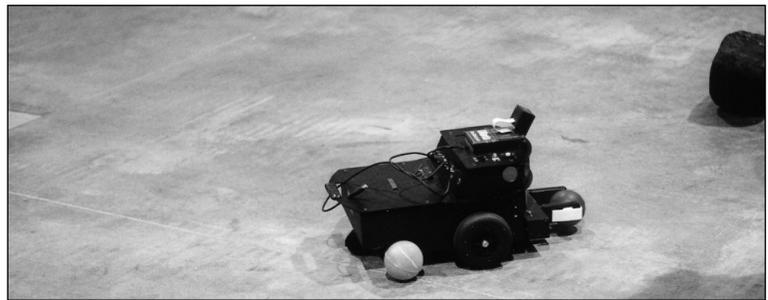
# The Competition Over the Years



*XAVIER, Carnegie Mellon University, Took Second Place in the 1993 Office Delivery Event.*



*GANYMEDE, IO, and CALLISTO from Georgia Tech, the Winner of the 1994 Office Cleanup Event.*



*Brown University's RAMONA in the 1997 Find Life on Mars Event.*



*CARMEL, University of Michigan, the Winner of the First AAAI Robot Competition.*



*Korea Advanced Institute of Science and Technology's CAIR-2 Won the 1995 Office Delivery Event.*



*University of Bonn's RHINO Won Second Place in the 1994 Office Cleanup Event.*



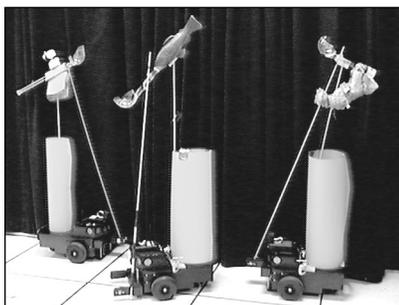
*The University of New Mexico's LOBOTOMOUS Won the Once-a-Week Cleaning Contest in the 1997 Home Vacuum Event.*



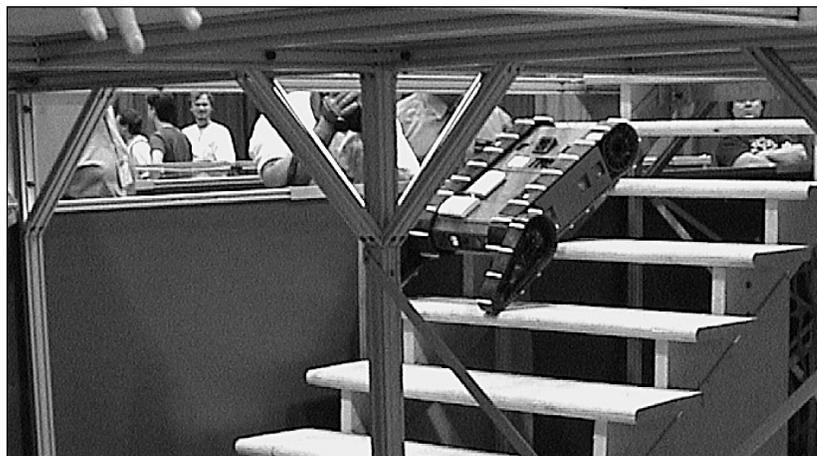
*Alfred the Penguin Butler from Swarthmore College Took First Place in the 1999 Hors d'Oeuvres, Anyone? Event.*



*OfficeBoy2000 (OB2K) from Carnegie Mellon University Was One of Only Two Entries in the First Robot Challenge Event Held in 1999. The Other Entry was Foof From the University of Southern California.*



*The Robotic Love Triangle from Brandeis University, the Crowd-Pleasing Winner of the First Hors d'Oeuvres Anyone? Competition Held in 1997.*

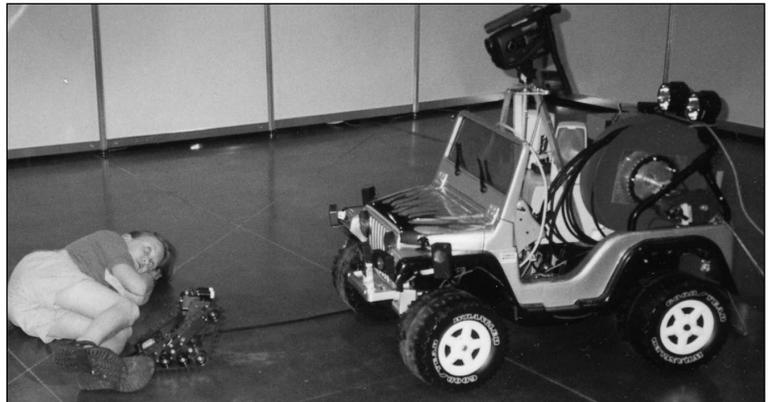


*The University of South Florida in the First Robot Rescue Competition at AAAI in 2000.*

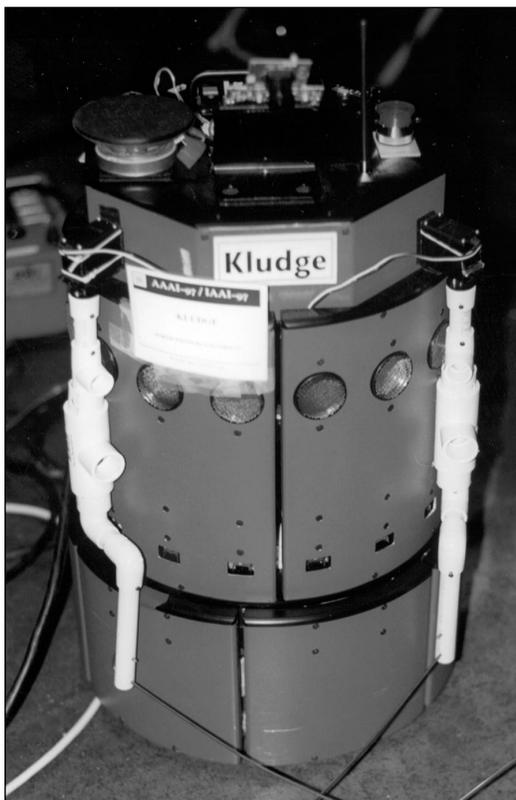
# The Exhibition Over the Years



*The 1994 Exhibition Was Host to the AIRS Hovercraft Robot from the University of Maryland.*



*Robots for Urban Search and Rescue Made Their First Appearance at AAI in the 1997 Exhibition: SILVER BULLET and BUJOLD from the Colorado School of Mines.*



*KLUDGE from Northwestern University Played Fetch with the Crowd at AAI-97.*



*SuBOT, a Highly Maneuverable Spherical Robot from Space Applications International Corporation, Was Demonstrated at the 1999 Exhibition.*

The winners of this year's events are given in figure 5. See the articles in this issue for discussions of the events and the research approaches of the participants.

## Toward the Future

As of this writing, the slate of events for the 2002 AAAI Mobile Robot Competition and Exhibition is still under discussion. This discussion, informed by our look back over the last 10 years, has led us to reflect on the objectives of the competition. Whatever the original objectives were, it has grown to become many more things to many people. For example, although we don't see as much cutting-edge research at the competition as we would like, we see many, many motivated and excited undergraduates building successful robots. Thus, in any realignment of objectives and component events, we want to be sure we preserve what is right with the competition.

There is no question that the AAAI Mobile Robot Competition and Exhibition should promote and showcase AI robotics: those aspects of robotics that require AI and those aspects of AI that enable successful robotics. However, the competition should also inspire and involve undergraduate students and provide a venue for graduate students to demonstrate their work. We feel these multiple goals can be met by providing several events that target different groups.

The Robot Rescue event will certainly be included because it offers a wide range of research challenges as well as extraordinary relevance in these times. The Hors d'Oeuvres, Anyone? and challenge events have been the primary drivers of human-robot interaction research over the last few years. Both Robot Rescue and Hors d'Oeuvres, Anyone? offer entry-level possibilities for undergraduates yet offer a deep enough problem that graduate students and researchers in the area will find interesting problems to solve. However, the overlap of human-robot interaction in Hors d'Oeuvres, Anyone? and the challenge suggests that we might find a way to combine the two into a new competition that could drive the field even farther.

This leaves us with the opportunity to establish a new event.... What will it be?

### Acknowledgments

Thanks to the Defense Advanced Research Projects Agency (DARPA), the Naval Research Lab, and Nils Nilsson for supporting the 2001 event. John Blitch, Doug Gage, Jim Hendler, Jean Schultz, and Mark Swinson at DARPA

*Figure 4. COYOTE, from the Navy Center for Applied Research in AI, Uses Speech and Gesture Recognition for Human-Robot Interaction at the 1999 Exhibition.*



### **Nils Nilsson Award for Integrating Artificial Intelligence Technologies**

CEREBUS

Northwestern University

### **Robot Rescue**

*Technical Award for  
Artificial Intelligence for Rescue*  
Swarthmore College

*Technical Award for  
Advanced Mobility for Rescue*  
Sharif University

### **Hors d'Oeuvres, Anyone?**

*First Place:*  
University of British Columbia

*Second Place (Tie):*  
Swarthmore College and Seattle Robotics Club

*Third Place:*  
Universidade de Aveiro

*Figure 5. The List of Winners from the 2001 AAAI Mobile Robot Competition and Exhibition.*

have provided critical advice and support this year and in the past. ActivMedia, iRobot, and Probotics donated robots at cost for prizes this year. The authors thank Tom Dean, Pete Bonasso, David Miller, Reid Simmons, and Alan Schultz for their recollections. The AI community owes a debt to the AAAI Mobile Robot

Competition and Exhibition chairs: Tom Dean and Pete Bonasso (1992); Kurt Konolige and Terry Weymouth (1993); Reid Simmons (1994); David Miller (1995); David Kortenkamp, Illah Nourbakhsh, and David Hinkle (1996); Ron Arkin (1997); Robin Murphy, Gregory Dudek, and David Kortenkamp (1998); and Alan Schultz (1999, 2000). Finally, the competition is made possible every year through the hard work of the American Association for Artificial Intelligence staff, especially Carol Hamilton, Keri Harvey, and Richard Skalsky.

### Note

1. Pete Bonasso, personal communication.
2. Tom Dean, personal communication.
3. Tom Dean, personal communication.
4. Pete Bonasso, personal communication.
5. Sebastian Thrun, personal communication.
6. Center for Robot-Assisted Search and Rescue web site, [www.csee.usf.edu/robotics/crasar/](http://www.csee.usf.edu/robotics/crasar/).

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