The AAAI 1999 Robot Events

Contests: Lisa Meeden & Alan Schultz
Challenge: Tucker Balch & Rahul Bhargava
Exhibition: Karen Zita Haigh & Marc Böhlen
Botball: Cathryne Stein & David Miller

1 Introduction

The Eighth Annual Mobile Robot Competition and Exhibition was held as part of the Sixteenth National Conference on Artificial Intelligence in Orlando Florida July 18 to 22, 1999. The goals of these robot events are to:

- Foster the sharing of research and technology.
- Allow research groups to showcase their achievements.
- Encourage students to enter robotics and artificial intelligence fields at both the undergraduate and graduate level.
- Increase awareness of the field.

The 1999 events included two robot contests, a new, long-term robot challenge, an exhibition, and a National Botball Championship for high school teams sponsored by the KISS Institute. Each of these events is described in more detail below.

2 The Contests

The contests require entrants to tackle a set of established tasks in a competitive environment. Contests of this kind are an important forum for getting robots out of the controlled environment of the laboratory and testing their robustness. Unique this year was the lack of a "penned area" in which to hold the contests. All the contests were held in the open exhibit hall with spectators around, and without any special marking of an "arena" or of the environment.

In the *Scavenger Hunt*, the entrants tried to locate a given list of items, just like the old party game. The objective of this contest was to create a forum for a wide variety of robotic skills to be displayed, such as object recognition, object manipulation, exploration and mapping. University of North Dakota's *Rusty*, built by Craig Eshenko, David Geise, Matt LaFary, and Mike Trosen, won first place. Second place went to Kansas State University's *Slick Willy*, done under the supervision of Dr. David Gustafson by Tim Beese, Frank Blecha, Jonathon Cameron, and Damon Kuntz. Third place was captured by University of Arkansas' *Electro*, with Dr. Douglas Blank as the advisor and students Jared Hudson, Brian Mashburn, and Eric Roberts.

In *Hors d'oeuvres, Anyone?* the entrants served finger-food items at the large reception of the AAAI festival for conference attendees. The objective was to unambiguously demonstrate interaction with the spectators. The teams' robots were encouraged to display distinctive personalities, to allow two-way communication with the spectators, and, if neces-

Figure 1: *Butler the Borg Shark*.

Figure 2: *Leguin the Puffer Fish*.

sary, to physically nudge spectators out of the way in order to better serve a wide area of the room. The *Hors d'oeuvres, Anyone?* contest had the largest number of entrants, and each team adopted a very different strategy.

Last year's winner, the team from the University of North Dakota, hoped to tightly integrate natural language processing, movement control and vision. However, they encountered serious compatibility issues and had to revert to a less integrated method. Their success in the scavenger hunt provided some solace for their difficulties here.

The University of South Florida team, directed by Dr. Robin Murphy with students Mark Eichenberg, Aaron Gage, Jeff Hyams, Mark Micire, Brian Minten, Min Shen, and Brian Sjoberg, collaborated with the school's theater department to create unique personalities for their pair of robots, pictured in Figures 1 and 2. The dominant robot, called the *Borg Shark*, was envisioned as a smarmy, aggressive character who served the food, while his helper, called the *Puffer Fish*, was designed to be a shy, reluctant partner who refilled the Shark's tray when summoned. This was the first team to ever bring a sewing machines to the contest! The *Borg Shark* and the *Puffer Fish* received a technical innovation award for *Conceptual and Artistic Design*.

The University of Arkansas team, also entrants in the scavenger hunt, served colored candies; their goal was to learn to distinguish the spoken words "orange," "brown" and "yellow" during the competition. Their robot, *Elektro*, asked a person to choose a color, offered the color it had heard, and then asked the person to give it appropriate feedback based on whether it had provided the correct color. Over the course of the two-hour competition, *Elektro's* speech-recognition performance improved noticeably. *Elektro* received a technical innovation award for *Integrating Machine Learning*.

The University of Southern California team, advised by Dr. Maja Mataric with students Brian Gerkey, Dani Goldberg, Monica Nicoleson, Stefan Weber, and Barry Werger, developed a human leg detector using a 180-degree laser sensor that proved to be a very reliable way to locate people in the crowded conference environment. Their pair of robots, based on South Park characters, were highly mobile, very audible above the din of conversation, and a favorite of the children in attendance. *Mr. Hanky* and *Cartman* took home third place.

The Robotics Institute team from CMU, directed by Dr. Illah Nourbashkh with student Chris Hardouin, located people by using pyroelectric sensors that registered changes in temperature caused by the motion of people walking nearby. This, too, proved to be a very reliable way to find people to serve. Their robot served cookies that were placed in a ring around the robot in front of its sonar sensors. As each cookie was removed, the robot could easily recognize that one had been taken. CMU's robot, called the *Texas Alien Woman*, was awarded second place.

This year's winner, the team from Swarthmore College directed by Dr. Bruce Maxwell and Dr. Lisa Meeden with students Nii Addo, Laura Brown, Paul Dickson, Jane Ng, Seth Olshfski,Eli Silk, and Jordan Wales, designed a penguin named *Alfred*, who had the personality of a proper English butler. *Alfred*, shown in Figure 3, located people to serve using vision-based motion detection and face detection. After approaching a person, *Alfred* checked a database of stored images to determine whether he might have interacted with the person before. If so, he referred to that person by a given nickname used previously; otherwise, he asked for an introduction. *Alfred* expected the people he served to speak properly, using "please" and "thank you" when appropriate, and scolded them when they failed to do so. When *Alfred* had been in one area of the room for too long, he used a floor-level nudging device to push through the crowd.

Figure 3: *Alfred* the penguin butler.

The robot contestants were evaluated by a panel of judges consisting of Ben Kuipers, Nils Nilsson, Alan Schultz, Chris Smith and Ben Wegbreit. This year, in addition to certificates, we awarded mobile, research robots for several categories. In each of the contests, a robot was awarded to the first and second place teams' home institutions. In addition, an award was given for the best integration across multiple AI techniques, the *Ben Wegbreit Award for Integrative Technologies*, which this year was won by the team from Swarthmore College. The awards consisted of Pioneer mobile robots from ActivMedia and ATRV-Mini and Megallen mobile robots from Real World Interface.

We would like to gratefully acknowledge travel support from the event's sponsors: the Defense Advanced Research Agency (DARPA), the Office of Naval Research, the Naval Research Laboratory, and AAAI. In addition, we would like to thank Dr. Ben

Wegbreit, ActivMedia, IS Robotics/RWI, and DARPA for their support of the robot awards.

3 The Robot Challenge

This was the inaugural year of the Mobile Robot Challenge. Our goal in establishing the Challenge is to "raise the bar" by presenting the robotics community with a task that drives ongoing research and provides an effective public venue for demonstrating significant new work.

The task for robots entering the Robot Challenge is, in short, to attend the National Conference on AI. Robots are initialized at the front door of the conference. From there, they must make their way (without a map) to the conference registration desk, wait in line, register, then proceed to a designated presentation room. Upon reaching the presentation area, they are to give a short presentation about themselves, and answer questions.

It was not expected that any robots entering in 1999 would complete the entire Challenge task—it is our hope, rather, that the Challenge will provide a focus for continuing research over the next five to ten years.

In 1999, two robots were entered in the Challenge: *OfficeBoy2000* from CMU and *Foof*, from USC. Both robot development teams focused on the first part of the task; namely, navigating from the front door to the registration desk without a map. The teams chose interactive methods to seek help from nearby humans in achieving their goal. Because the event was held in the conference hotel, hotel guests and conference attendees were able to interact with the robots during the trials.

USC's entry, *Foof*, uses an interactive, behavior-based solution to the navigation task. Their robot carries a florescent orange-colored arrow that humans can use to point it in the right direction. When the arrow is lifted from the bracket that holds it, a sensor switch notifies the robot. It then looks for the arrow and uses a reactive strategy to align with it. Once the arrow is replaced in the carrying bracket, the robot proceeds on its way, in the direction provided by the human. *Foof* is an Activmedia Pioneer robot equipped with a pan-tilt color camera and a speech synthesizer.

Humans are an often ignored source of information about the world that robots might use to accomplish their missions. The *Office-Boy2000* (OB2K) team sought to develop a system that could exploit this resource. Primary goals in developing this robot included:

- Support a high level of human interaction to enable the robot to use humans as a source of task-oriented information.
- Implement an extensible mobile robot programming architecture that integrates existing artificial intelligence and robotics techniques.
- Simplify human-robot interactions by designing a useful, amusing character.

OB2K, pictured in Figure 4 was assembled from commercial off the shelf components, including a Nomadic Technologies' Nomad Scout robot, a laptop computer and computer speakers.

The robot interacts with the environment around it to complete a task. With speech synthesis and a screen-based GUI, OB2K takes advantage of human computer interaction methods that are already familiar to most people. If lost, OB2K yells and spins until someone helps it. If confused, it finds someone to ask for help and pesters that person (in an amusing way) until they do.

The OB2K software architecture is based on a 3-tiered approach consisting of a parser, a sequencer, and a motion controller. All information the robot learns about the world is stored

Figure 4: *OfficeBoy200* wandering through the hotel lobby asking for directions to the registration desk.

in a dynamic knowledge base that is updated and referenced while the robot attempts to complete its assigned task. The robot is programmed with several low-level skills that can be executed by the motion controller. These skills are associated with tasks and actions that the robot can complete, and assembled into useful plans by the robot.

To use OB2K, people type in a natural language command on a laptop-based GUI. Once the user provides enough information through the GUI to define a a goal state, OB2K draws on its skill set to achieve it. OB2K parses the natural-language input, then passes caseframes to the sequencer to plan over. The sequencer plans the tasks it needs to complete and sends motion commands through the controller to the mobile robot platform. The architecture makes it easy to incorporate new skills, so that more complex problems can be solved.

OB2K was tested on people ranging from Brazilian tourists to AI professionals during the days before the demonstration. During the Challenge, the robot was able to navigate from the entrance to the registration desk. It successfully recruited humans in the area to point it in the right direction and tell it how far it was to the desk. OB2K is also able to use a map (if one is provided) to navigate to a room and carry out tasks like delivery and monitoring an assigned area.

OB2K was built and programmed by Rahul Bhargava, Christopher Quirk and Daniel Robinson. Illah Nourbashkh of the CMU Robotics Institute advises the team.

The challenge contestants were evaluated by a panel of judges consisting of Henry Hexmoor, Ian Horswill, Leslie Kaelbling, Sven Koenig, and Ben Kuipers.

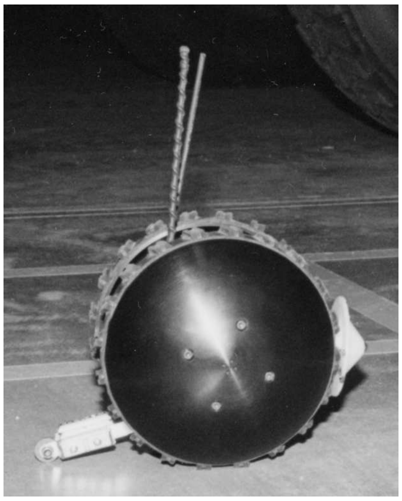

Figure 5: *SuBot*.

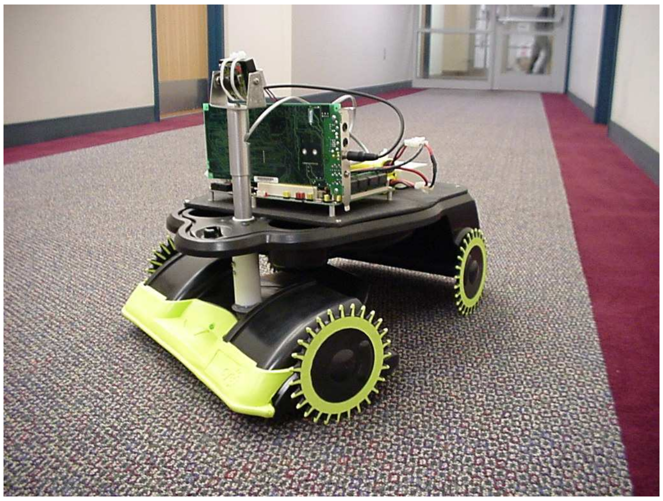

Figure 6: *Minnow*.

4 The Robot Exhibition

The robot exhibition gives researchers an opportunity to showcase current robotics and embodied-AI research that does not fit into the competition tasks. In an effort to increase awareness of the field, we hope to encourage a wide variety of robots and embodied AI research. This year continued the trend towards novel hardware platforms and advancing high-level robotic capabilities, including human interaction.

There were three exhibits primarily showcasing novel hardware platforms.

SuBot, by Jennifer Herron and John Spofford from SAIC, is a highly maneuverable spherical robot designed for indoor and outdoor reconnaissance in confined spaces (Figure 5). Currently tele-operated, *SuBot* will provide an excellent platform for future software development.

Babycakes, designed and built by undergraduates Michael Rosenblat and Morgan Simmons and graduate student Ercan Acar from Carnegie Mellon University, is a platform to test complete coverage algorithms, with applications in landmine recovery. *Babycakes* efficiently and completely explores unknown regions.

Cye is a new commercial robot from Probotics. *Cye* was designed for the household robotics market, and hence is cheap, compact, and easy to use via an intuitive graphical user interface. Using extremely accurate dead reckoning and calibration techniques, *Cye* navigates around its environment, vacuuming or pulling a wagon full of items.

On the theme of developing inexpensive high-performance robots, Tucker Balch Jim Bruce, Anna Rillo, Sorin Achim, and Manuela Veloso from Carnegie Mellon showed *Minnow* (Figure 6). The mechanical platform is based on the commercially available Cye, controlled by the *TeamBots* architecture (formerly called *JavaBots*). *TeamBots* is available at `www.cs.cmu.edu/~trb/TeamBots/`. Minnow will form the basis for research in robot teams operating in dynamic and uncertain environments.

Like *TeamBots*, the *Web-based Robot Simulator* by Dan Stormont at the University of New Mexico provides a strong foundation for developing and testing algorithmic approaches. The simulator uses VRML 2.0 and Java to simulate the operation of a mobile robot in a dynamic environment. The simulator allows the user to place and move objects in an office-like environment, select different robot chassis designs, and run various robot navigation algorithms in the form of Java applets. The web-based simulator is available from `www.usu.edu/~afrotc/cadre/stormont/vrml.html`.

A new approach to robotics was demonstrated by Dr. Robin Murphy at the University of South Florida: marsupials. Marsupial robotics research offers several unique research challenges, including: control of high mobility systems, data communications, charge docking, cooperative sensing, and cooperative motion. Murphy supervised a team of NSF-funded undergraduate women who demonstrated an Urban Search-and-Rescue team, *Silver Bullet* and *Bujold*, shown in Figure 7. *Bujold* is a micro-rover designed for maneuverability in small spaces, carried for longer distances and over more challenging terrain inside *Silver Bullet*.

IS Robotics, in collaboration with Murphy, also demonstrated a marsupial team. The team is comprised of an ATRV Robot functioning as a mobile "base station" for an *Urban Robot*. The *Urban Robot* employs its unique stair climbing locomotion mechanism to deploy from, and return to, the ATRV-mounted base station.

One major theme evidenced in this exhibit was an increased trend towards robot-human interactions. In the 1998 exhibit, there were several robots showing human-centered capabilities, and this year continued and expanded that theme.

One step towards increasingly autonomous systems was demonstrated by Darrin Bentivegna at Georgia Tech. Bentivegna is exploring the task of *Learning By Observation* to effectively reduce system training time. He demonstrated the techniques in two domains: a virtual air-hockey player, and a 3D labyrinth game. In the labyrinth game, a player controls the movement of a marble by tilting the platform using two knobs. The object of the game is to move the marble through a maze that contains holes in which the marble can fall into. After observing a particular human player, the learner will exhibit some of his characteristics, often exceeding the human's capabilities.

Alan C. Schultz and his team from the Navy Center for Applied Research in AI brought *Road Runner*, which explores adjustable autonomy. Using a Palm Pilot, the human can use different levels of control in a series of navigation tasks. *Road Runner* integrates research in navigation, continuous localization, exploration, map building, and path planning. The robot can move into unknown areas, build a map while staying localized, plan paths, and adapt to rapid changes in the environment. Schultz also demonstrated *Coyote*, a robotics research project dealing with multi-modal communication. *Coyote* combines a natural language understanding component with a gesture recognition system to allow freer human-robot interaction. *Coyote*, shown in Figure 8, is an important step towards full-fledged, natural communication.

Human-centered communication was also the focus of a second project from Dr. Murphy (University of South Florida). *Butler* and *Leguin*, shown in Figures 1 and 2, are a pair of highly colorful cooperating heterogeneous robots (that also entered the competition). Along with advances in the use of computer vision, sensor fusion, and dynamic sensor allocation, *Butler* and *Leguin* attempt to en-

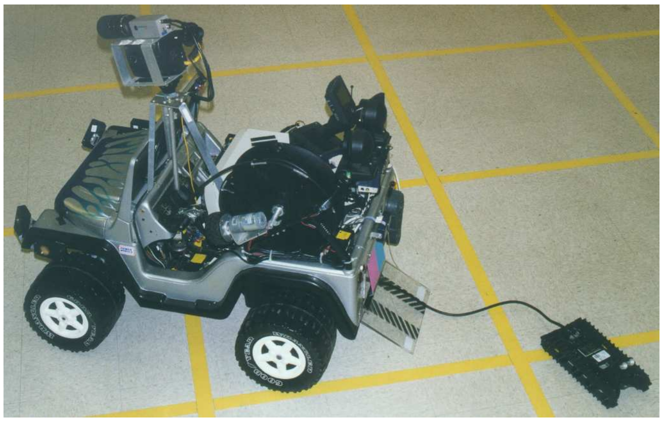

Figure 7: *Silver Bullet* and *Bujold*.

gage and interact with the audience. This exhibit focussed on how the USF Art department helped create "delightful" robots using interactive media, and how AI constrained Art and vice versa.

The final exhibit was also artistically inclined. *Robot Improv* developed by Allison Leigh Bruce, Brian Magerko, and Sam Listopad under Illah Nourbakhsh's supervision at Carnegie Mellon University is a pair of robots that do improvisational acting. There is no pre-determined script, only sets of available actions and dialog for the actors to choose from. Each play is improvised at run-time. The actors use believable behavior and a high level of communication to act out dramatic plays.

The robot exhibit has traditionally been a place for demonstrating unusual and state-of-the-art robotic capabilities, and 1999 was no exception. The exhibits demonstrated a wide variety of embodied AI technologies, and in the years to come we expect to see robotics making inroads into almost every aspect of day-to-day life.

5 The Botball Tournament

University students and AI professionals were not the only participants in the Robot Exhibition Hall. Seventeen high school and middle school student teams from across the country brought small, autonomous mobile robots, made from specialized robot kits, to compete in the first annual National Botball Tournament.

Botball is a national program of KISS Institute for Practical Robotics. It is designed to get middle and high school students excited about science, math, and technology, and to help them develop skills and learn more about engineering, AI and computer science. Botball also offers a vision of a rewarding career path in technology that students may not have previously considered.

In Botball, student teams have about six weeks to design, build, and program (in C) an autonomous mobile robot, about the size of a toaster. The robots must be able to play the Botball game (which changes every year) in a head-to-head, double-elimination tournament. The robots must start by themselves, play for 90 seconds, then stop by themselves.

Figure 8: *Coyote* recognizing gestures.

Botball also contains a separate robot design and website creation competition.

This 1999 tournament was played on a $4x8$ foot arena and involved each team trying to move its color of ping pong balls into the opponent's goal area: one point for each ball over the goal line and five points for each ball in the corner pocket. In addition to offense, many teams had their robots set up barriers to try to block their opponents from scoring.

The crowds cheered wildly at this years' National Botball Tournament, as *Fembot*, a robot created by the all-girls team from Oak Ridge High School, in California, boldly flung itself across the arena, lego arms extended, shoving its ping pong balls across the arena into the opponents goal. The team from Oak Ridge gave their robot both brains and brawn (but mostly brawn), not to mention an impressive speed that helped it achieve its goals.

Fembot was not the only star of the show. Menlo-Atherton High School's robotics team produced *Minotaurus*, a remarkable robot that played the game brilliantly, scooping up ping pong balls in its rotating combine-like collector on one end, passing the balls up into a holding chamber, seeking the goal zone, then depositing only the correctly colored balls into the high scoring position, ejecting its opponent's balls from the playing field. During the seeding rounds *Minotaurus* achieved the maximum score all three times (no other team got the maximum even once).

What made *Minotaurus* unique among all the Botball robots was its amazing ability to play in any of several personality modes, which could be chosen at the last minute by the team members. Demonstrating a sportsmanship rarely found in the world today, *Minotaurus* could either play nicely by attempting to score points while ignoring its opponent, or it could play an aggressive game, in which it placed the wrong colored balls in its opponent's goal causing them to have a negative score. The Menlo-Atherton team would make the appropriate attitude adjustment just before the round based on earlier observations of each opponents' strategy displayed in previous or seeding rounds.

"This has been by far my best experience in high school. By far!" exclaimed one member of the Menlo-Atherton team. The team, from Menlo-Atherton, California won the overall National Botball Championship for 1999, winning the highest combined score from seeding and head-to-head rounds. *Agitator*, from Allen D. Nease High School in Jacksonville, Florida took second place in the overall tournament, and *Fembot* from Oak Ridge High School took third place in the overall scoring, although it came in first in the head-to-head competition.

Over one hundred high school and middle school roboticists attended AAAI 1999, participating in the national Botball Tournament. These students enjoyed mingling with the university students and professionals who were displaying their own robots. After watching these professionals, the reactions from the students varied from "Wow!" to a blasé "I can do that." For almost all of the students, AAAI was the first technical conference they had ever attended, and all were impressed by the experience.

KISS Institute conducts regional Botball Tournaments around the country, then invites all the teams to participate in the National Botball tournament, which is hosted by AAAI, who also supplies travel grants for the top teams from each region. Other major sponsors of the 1999 Botball Program, in addition to AAAI were NASA Goddard Space Flight Center, NASA Ames Research Center, the Education Foundation of Fairfax Virginia and the University of Oklahoma College of Engineering. More details about Botball can be found at `www.kipr.org`.

6 Y2K Robot Events

Plans are well underway for the upcoming robot events to be held at the AAAI 2000 meeting at the end of July in Austin, Texas. We plan to continue the theme of realistic environments and may modify the scavenger hunt contest towards an urban search and rescue task.

Once again, a day-long workshop will be held for the robot contestants and exhibitors at the close of the conference. The purpose of this workshop is to allow team members to understand and benefit from each others efforts. Each group presents the research behind their entries. A proceedings of the 1999 workshop will be available as an AAAI technical report published this winter.

We expect even more teams this year, and we would particularly like to encourage more international interest. Previous years have had teams from around the world. Limited student travel and robot shipping support are available on a first-come, first-served basis. See http: //www.aic.nrl.navy.mil / schultz /aaai2000/