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AAAI-98 Robot Exhibition

Karen Zita Haigh and Tucker Balch

■ The robot exhibition had a very successful 1998. At the conference, we had 11 robot demonstrations (including three multirobot demos), 5 oral presentations, and an additional 5 video or poster submissions. The exhibition also included a published video proceedings for the first time. One of the most interesting features of the exhibition was the variety of capabilities shown. From a mechanical point of view, indoor wheeled robots were, as usual, the most common form of robot, but the exhibit also featured several outdoor wheeled robots, several legged robots, two humanoids, a snake, and a plant. From a software perspective, the exhibit featured general-purpose robot-control software, vision, teleoperation, language learning, teamwork and expression of emotion. A significant number of entries addressed the important, emerging research area of robot-human interaction, both for entertainment purposes and ease of use.

Walk into a typical, high-tech office environment, and among the snaking network wires, glowing monitors, and clicking keyboards, you are likely to see a plant. In this cyborg environment, the silent presence of the plant fills an emotional niche. Unfortunately, this plant is often dying; it has not adapted to the fluorescent lighting, lack of water, and climate controlled air in the office. OFFICE PLANT #1 (OP#1), developed by Michael Mateas and Marc Böhlen from Carnegie Mellon University (Böhlen and Mateas 1998), is an exploration of a technological object, adapted to the office ecology, which fills the same social and emotional niche as a plant. OP#1 monitors the ambient sound and light level and utilizes text classification techniques to monitor its owner's e-mail activity. Its robotic, sculptural body, shown in figure 1, reminiscent of a plant form, responds in slow, rhythmic movements to express a mood generated by the monitored activity. In addition, low, quiet, ambient sound is generated to express this mood; the combination of slow movement and ambient sound thus produces a sense of presence, responsive to the changing activity of the office. OP#1 is a new instantiation of the notion of *intimate technology,* that is, technologies that address human needs and desires as opposed to technologies that exclusively meet functional task specifications.

OP#1 was not the only artistic robot presented at the American Association for Artificial Intelligence (AAAI) 1998 Robot Exhibition and Competition. The robot exhibition showcases current research in robotics that falls out of the scope of the competition and, hence, attracts a wide variety of robotics demonstrations. The 1998 exhibition featured many forms of locomotion, including a snake, legged robots, indoor wheeled robots and outdoor wheeled robots. OP#1, along with a face and a humanoid torso, used motion solely as a method of expressing emotion. About half of the exhibitors brought their robots, and the rest gave talks, presented posters, or participated only in the video loop. Table 1 shows the list of participants and their affiliations.

PEPE, the personal pet, is another of the entertainment-oriented robots. PEPE's developers, Alexander Stoytchev and Rawesak Tanawongsuwan, gave a presentation about this small PEBBLES III–class robot manufactured by IS Robotics (figure 2). The long-term objective of this Georgia Institute of Technology research project is to build an intelligent, adaptive, user-friendly agent that displays different pet-like emotional states and a wide range of behaviors. PEPE will interact with, and learn about, its user as naturally as possible, thus making the user perceive PEPE as a pet rather than a toy.

PEPE's underlying architecture is another Georgia Tech project, JAVABOTS, developed by Tucker Balch. JAVABOTS is a new system for developing and executing control systems in simulation and on mobile robots. JAVABOTS provides an easy-to-use robot simulator that can

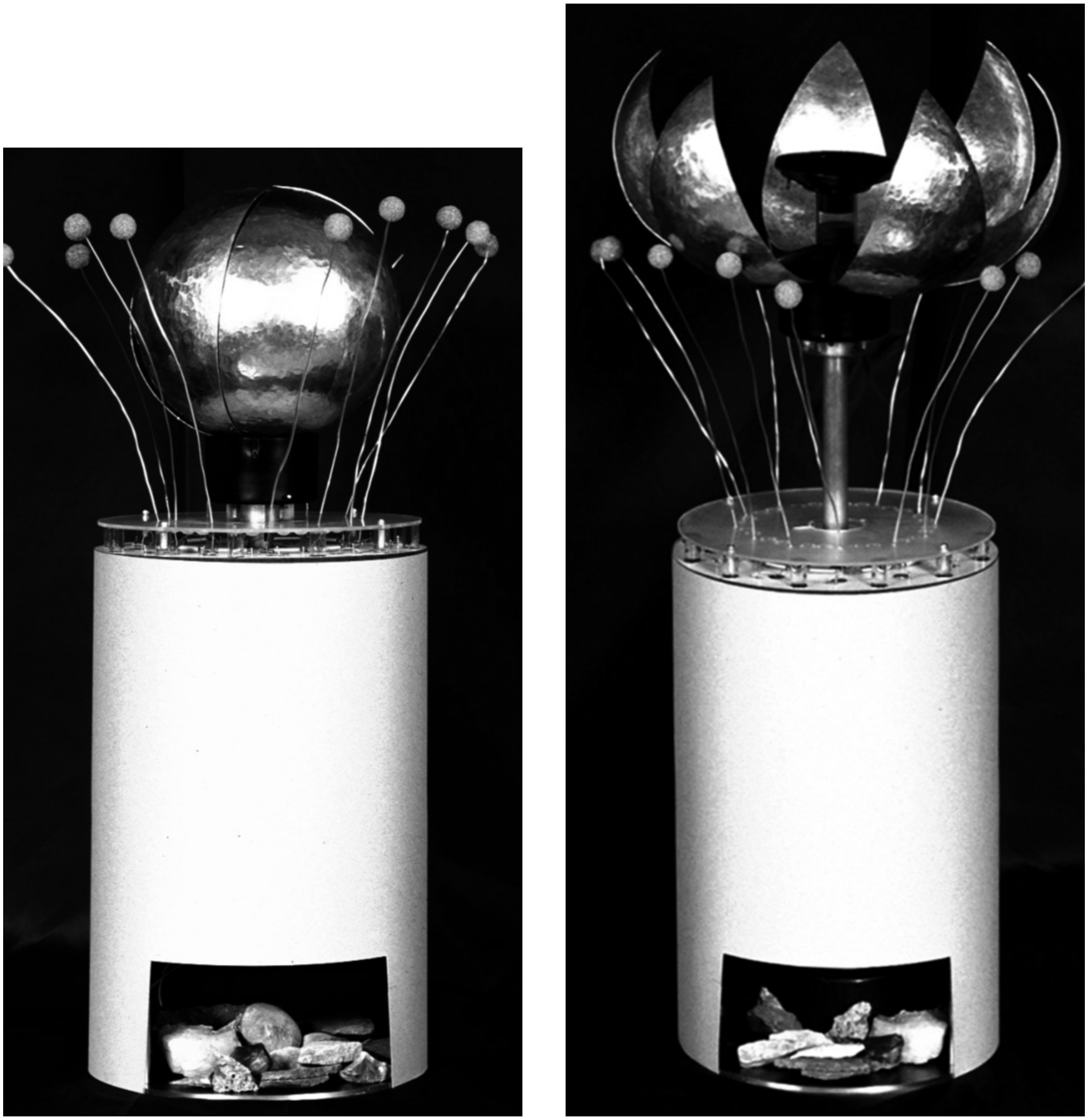

Figure 1. *OFFICE PLANT #1.*
A. Resting. B. Blooming.

be downloaded from the internet. Individual and multirobot simulations are supported, including multiple robot types simultaneously. The JAVASOCCER robot soccer simulation included with JAVABOTS is popular among people new to robotics, and it has also been used in several introductory robotics and AI courses as the basis of class projects. JAVABOTS is also an important tool in mobile robotics research. Its object-oriented design enables researchers to easily integrate sensors, machine learning, and hardware with robot architectures. The winning Find Life on Mars robots in the AAAI-97 competition were driven by JAVABOTS control systems. JAVABOTS is being used in several other ongoing research efforts, including PEPE, RoboCup robot soccer, and foraging robot teams.

COG is a third robot designed to interact socially with humans. COG is an upper-torso

	Autonomous Robots	
OFFICE PLANT #1	Michael Mateas, Marc Böhlen	Carnegie Mellon University
CMTRIO	Manuela Veloso, Will Uther	Carnegie Mellon University
Sony PETS	Ian Horswill, Dac Le	Northwestern University
KLUGE	Ian Horswill, Dac Le	Northwestern University
MINDART	Maria Gini	University of Minnesota
TBMIN	Maria Gini, Paul Rybski	University of Minnesota
THE SPIRIT OF BOLIVIA	Barry Werger, Goskel Dedeoglu	University of Southern California/ULLANTA
NOMAD	Reid Simmons, Mark Maimone	Carnegie Mellon University
XAVIER	Reid Simmons	Carnegie Mellon University
	Remote-Controlled Robots / Hardware Platforms	
ATRV-2	Tyson Sawyer	Real World Interface, Inc.
STRIDE	Sarah Finney Stereo Perception	IS Robotics
URBAN ROBOT	Sarah Finney	IS Robotics
PEPE	Alexander Stoytchev, Rawesak Tanawongsuwan	Georgia Institute of Technology
COG	Rodney Brooks	Massachusetts Institute of Technology
KISMET	Cynthia Breazeal, Brian Scassellati	Massachusetts Institute of Technology
BEAST	Laurent Chabin	Independent
SNIKY THE SNAKE	Laurent Chabin, Roger Crochin	Independent
	Robot Capabilities / Software Architectures	
	Kurt Konolige, Chris Eveland	SRI International
BABU and PI: Language	Paul Vogt	Vrije Universiteit Brussels
JAVABOTS	Tucker Balch	Georgia Institute of Technology

Table 1. AAAI-98 Robot Exhibition Participants.

humanoid robot, developed at the Massachusetts Institute of Technology (MIT) under the supervision of Rodney Brooks, that was designed to investigate issues of embodiment, human development, social interaction, and large-scale system integration. The poster and video exhibits described some of COG's current capabilities, including face detection, eye finding, imitation of head nods, oscillator-controlled rhythmic motion, a vestibular-ocular reflex, and simple visual routines.

KISMET, COG's face (figure 3), was developed by Cynthia Breazeal and Brian Scassellati at the MIT AI Lab. KISMET integrates perception, attention, drives, emotions, behavior selection, and motor acts. The robot perceives both salient social stimuli (faces) and salient nonsocial stimuli (motion). The robot responds with expressive displays that give the human cues about how to satisfy the robot's drives but neither overwhelms nor understimulates the robot. Breazeal and Scassellati presented a poster describing experiments where a human

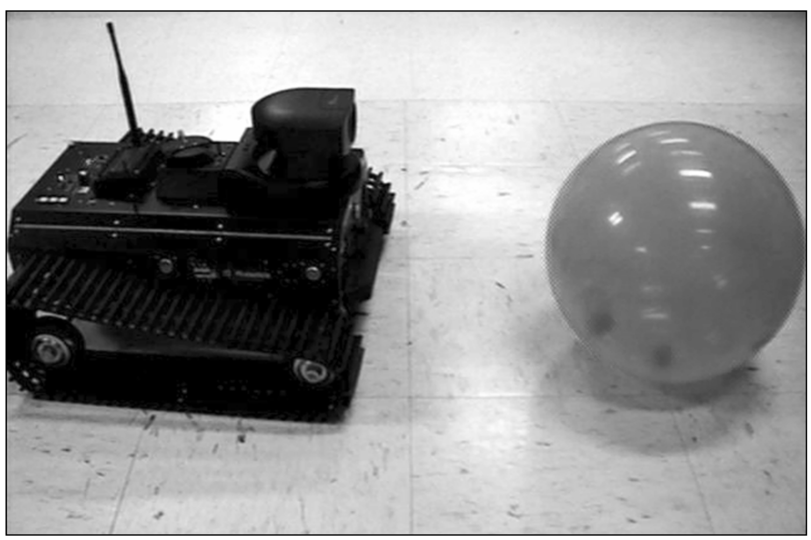

Figure 2. PEPE.

engages the robot with a toy or face-to-face exchanges.

Vision systems are an important part of

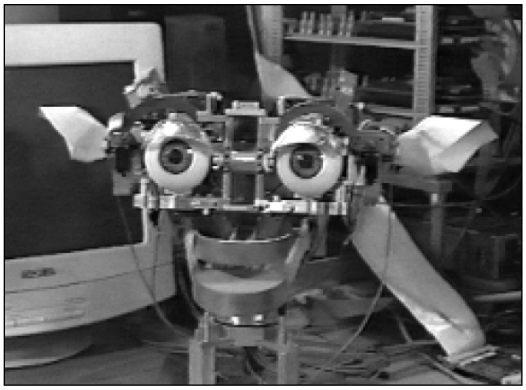

Figure 3. KISMET.

many robotic systems, and one exhibitor addressed this problem directly. Kurt Konolige of SRI International and Chris Eveland of the University of Rochester presented a small real-time stereo vision system (Konolige 1997). Stereo sequences promise to be a powerful method for segmenting images for applications such as tracking human figures. Konolige and Eveland have developed a method of statistical background modeling for stereo sequences that improves the reliability and sensitivity of segmentation in the presence of object clutter. The dynamic version of the method, called *gated background adaptation,* can reliably learn background statistics in the presence of corrupting foreground motion. During the exhibit, they demonstrated their method by tracking people in the exhibit hall. The method was demonstrated with a simple head discriminator at video rates using standard PC hardware.

Language learning is another area of research that will enable robots to interact more closely with humans. Paul Vogt, from Vrije Universiteit Brussels in Belgium, gave a presentation of BABU and PI. He has two robots engage in a series of language games, allowing them to form concepts about interesting sensor information. The robots are two small Lego vehicles with on-board sensorimotor processing and a radio link. Two motors control the robots' movements, and three different low-level light sensors perceive the different objects in their surroundings. A PC that receives the robots' sensory data is used to perform the higher-level cognitive processing. Initially, the robots only have knowledge about how to observe their surroundings and how to communicate. Concepts are formed around a set of features that discriminate an object from other objects in their environment. If no distinction can be found, new features can be generated. The lexicon is formed within a *naming game* model, where the speaker (one of the robots) encodes a word from the concept of one object. The listener (the other robot) decodes the uttered word into a set of corresponding concepts, and if one (or more) of these concepts in turn corresponds to the meaning of one of the

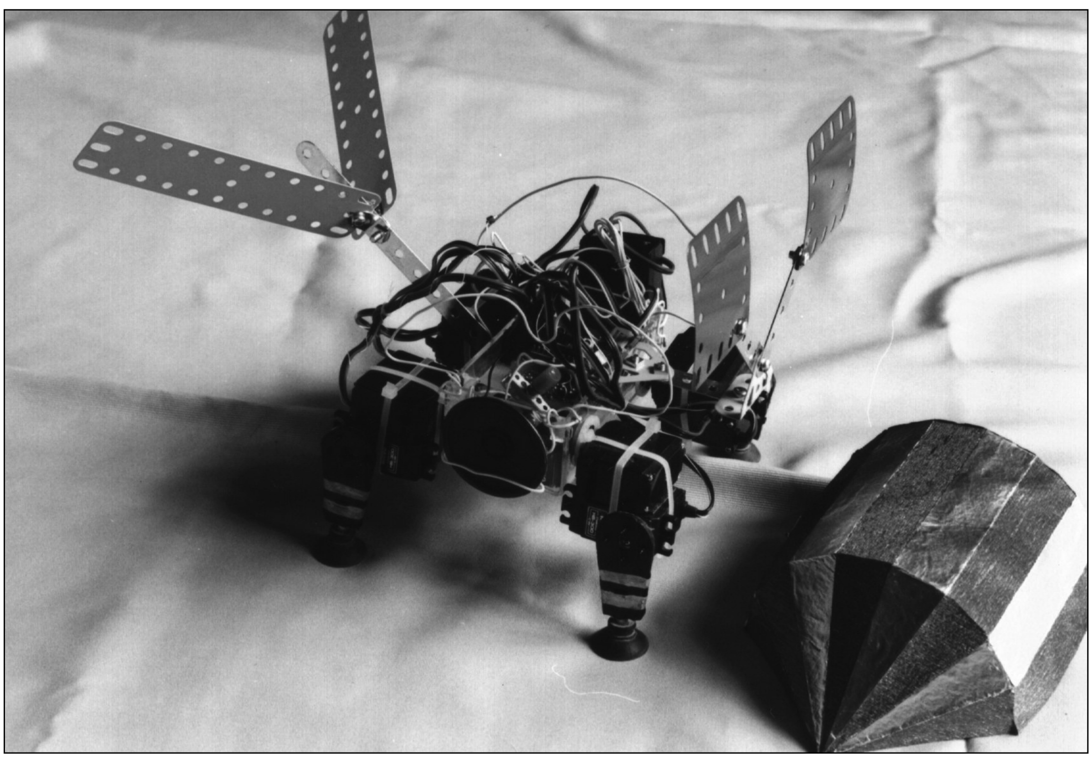

Figure 4. BEAST.

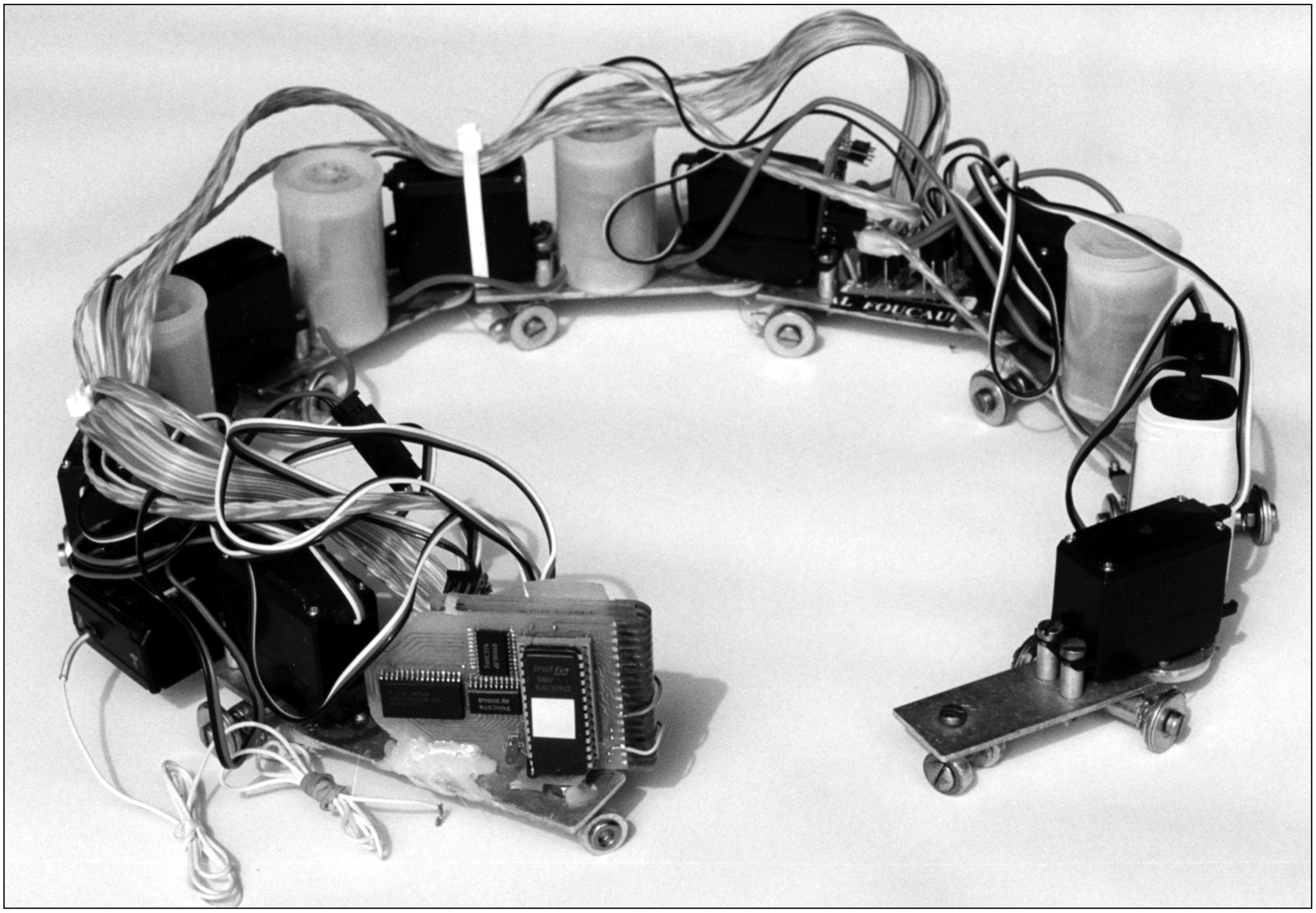

Figure 5. SNIKY, *a Mechanical Snake.*

observed objects, the naming (and, thus, language) game can be a success. Success is complete when both robots agree that they have communicated the same object. Otherwise, the lexicon is adapted by word-creation or word-meaning adoption.

Another robot developed to address human desires, rather than perform explicit tasks, is BEAST, a remote-controlled robot that looks like a crab when walking sideways. The developer, Laurent Chabin from Versailles, France, submitted a video of the four-legged mobot (figure 4). BEAST's possible uses are purely in the eye of the beholder; Chabin says, "This machine will have the purpose you find for it."

Chabin, along with Roger Crochin, also sent video describing SNIKY, a mechanical snake (figure 5). SNIKY is composed of nine wagons, each with two wheels. It is manually remote controlled, with one channel to control head direction and one channel to control the rate that the head position is copied toward the tail. By taking an S shape and forcing the movement to propagate tailward, the snake uses friction to push itself forward. The remote control allows the user to explore different movement strategies for different terrains.

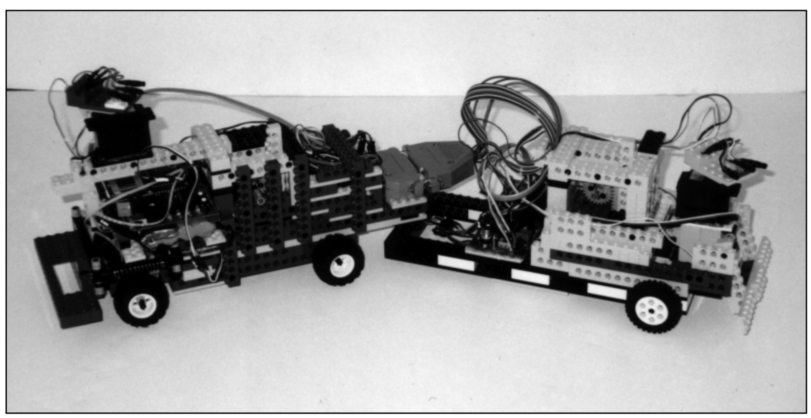

Figure 6. TBMIN.

Another system that demonstrated complex handling of joints was TBMIN, a trailer-backing minirobot by Paul Rybski and Maria Gini at the University of Minnesota (Hougen, Rybski, and

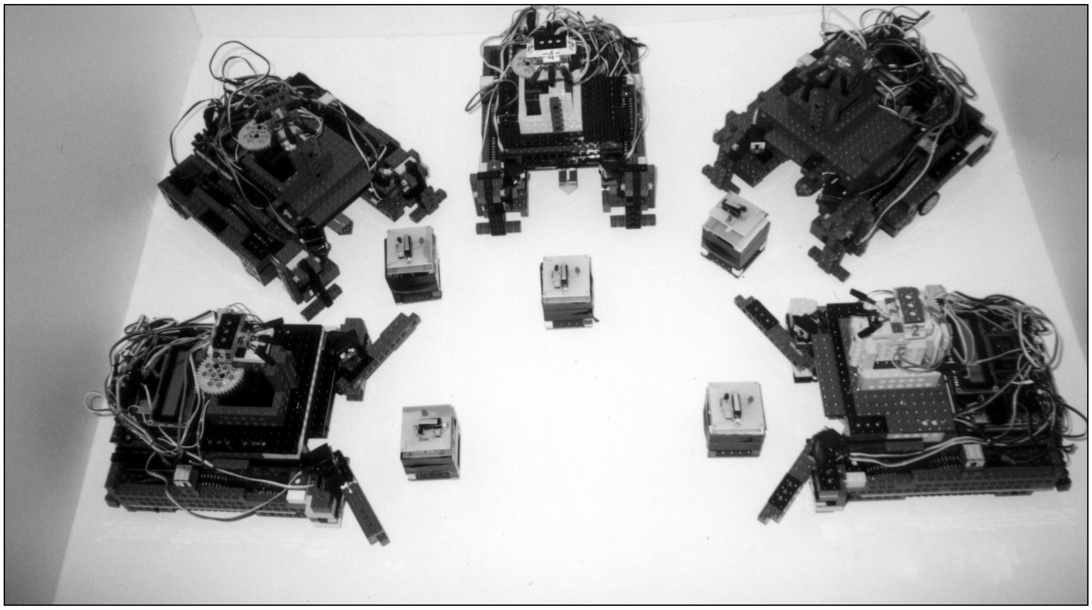

Figure 7. MINDART*: Robots and Targets.*

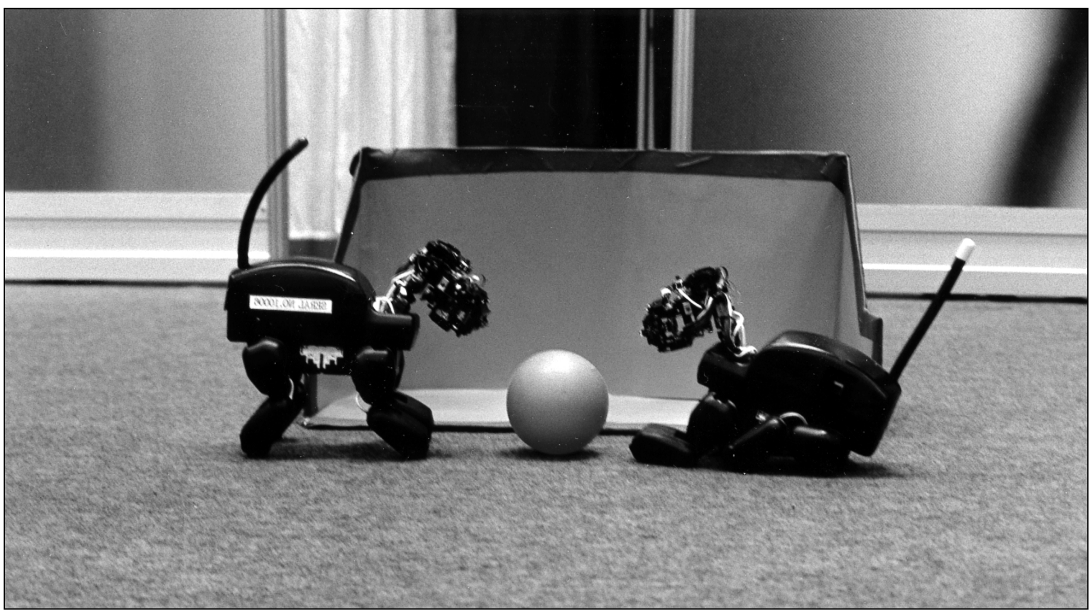

Figure 8. CMTRIO.

Gini 1999). TBMIN is a Lego robot, shown in figure 6, controlled by an on-board HANDY BOARD. TBMIN learns how to back a car and trailer rig to a target location by steering the front wheels of the car. The system uses laterally connected artificial neural networks to improve the efficiency of a basic reinforcement learning mechanism. The input consist of the hitch angle and the angle of the trailer to the target; the output is what direction to turn the steering mechanism. The system succeeds if it reaches the goal and fails if it jackknifes, or the goal angle exceeds 90 degrees. UMinn is currently extending the software to reverse a car with a double-trailer connection.

UMinn demonstrated a second group of Lego-based autonomous robots, called MINDART (Minnesota distributed autonomous robotic team) (Rybski et al. 1998), shown in figure 7. MINDART was designed to study how to use multiple robots to efficiently solve problems. The robots find and collect target objects and return them to a home base. The targets transmit a constant stream of infrared light that the robots can detect. When a robot is close enough to a target, it slides its lifting mechanism and picks up the target. The robot then delivers the target to the home base, tracked by photoresistors mounted on top of a turret that can turn 360 degrees. The on-board computer is a HANDY BOARD programmed using INTERACTIVE C. The robots' programming is completely reactive. They do not maintain any record or map of their environment, and they do not communicate with each other.

Following the theme of teamwork, two sets of soccer-playing robots appeared at the exhibition. The first, THE SPIRIT OF BOLIVIA (figure 8), was developed by the University of Southern California and the robotic theater troupe, ULLANTA, under the direction of Barry Werger and Goksel Dedeoglu. Two members of their middle-size RoboCup team demonstrated their skills by playing against each other as well as the audience. One was the fielder named NINANINA, a PIONEER AT robot controlled by a PC104 processor running AYLLU under QNX; the other was the goalie PAPA WAYK'U, a B14 base, with two Cognachrome vision systems, which was built by Newton Laboratories. The goalie localized itself using the white lines near the goal while moving extremely rapidly to intercept the ball. The fielder combined sonar-based obstacle avoidance with compass and dead-reckoning localization to interact safely with humans and other robots. It also used vision-based ball and goal identification to direct its movements, safely lining up with the goal and manipulating the ball. Programming was done with a strict behavior-based approach that resulted in robust and sophisticated behavior being generated by a minimal amount of code. When the full team plays together (four fielders rather than one), team cooperation "emerges" from the sonar avoidance and ball-manipulation behaviors.

The second soccer-playing team was based on more unconventional hardware: Sony Corporation's legged pet robots. These robots are yet another example of the entertainment focus of many of the robots at the exhibit. The Sony pet robots were demonstrated by CMTRIO, a team from Carnegie Mellon University that included Manuela Veloso and William Uther (Veloso and Uther 1999). The quadruped robots, shown in figure 8, have 16 degrees of freedom and include a color camera with built-in real-time color-separation hardware. All processing is on board. The current models have no communication capabilities apart from vision that allows them to recognize the uniform of their teammates and opponents. Along with the robots, Sony supplied a software library that allows the robot to walk in a given direction and stand up when it falls over.

Figure 9. XAVIER.

CMTRIO demonstrated its soccer-playing abilities following its recent win at RoboCup-98's legged robot soccer competition in which all entrants had exactly the same hardware platform, with team-specific software (for more information about the RoboCup competition, see www.robocup.org/ and the article by Veloso et al., also in this issue). CMTRIO (figure 8) used a layered control architecture, with two particularly important aspects: First, CMTRIO used a supervised gradient-descent learning algorithm to calibrate the color-separation hardware. Second, CMTRIO used a Bayesian localization mechanism that allowed the robots to use landmarks around the field to maintain the direction and distance to the goal even when the goal was out of sight.

Sony's robots were also used by the team from Northwestern University (NWU) under the direction of Ian Horswill and Dac Le. NWU showed its software development environment (Horswill 1997), which includes a multithreaded Lisp interpreter as well as ports of the visual navigation and object-tracking facilities developed for its other robot, KLUGE. KLUGE is a cylindrical robot with an omnidirectional wheeled

Figure 10. NOMAD *in the Atacama Desert.*

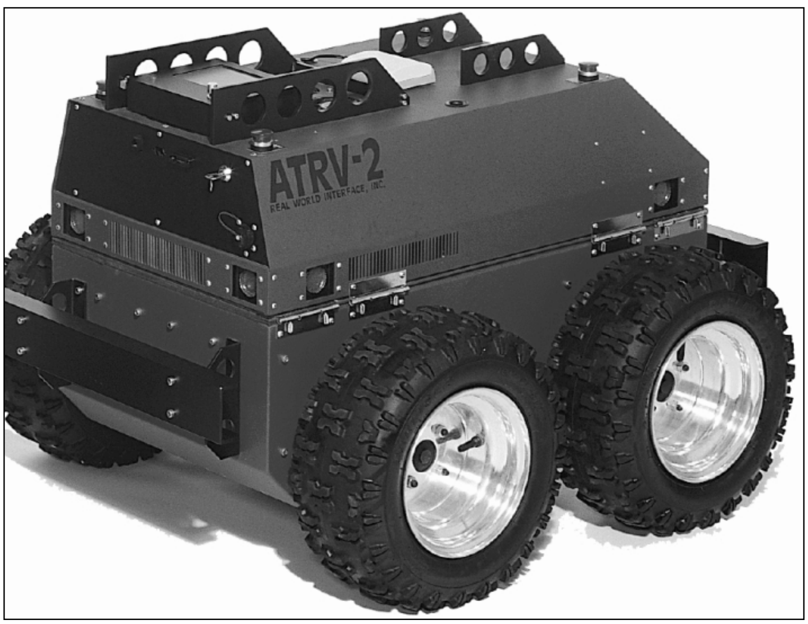

Figure 11. ATRV-2.

base. KLUGE uses an on-board, low-power digital signal processor with attached frame grabber to perform high-speed visual navigation and object tracking. KLUGE's demonstrations included high-speed collision avoidance, person following, game playing (fetch), and simple natural language instruction following. In one of its demonstrations, KLUGE would seek out a moving individual and persistently follow him/her until it "got bored."

Another cylindrical robot involved in the robot exhibition was XAVIER (figure 9), developed under the supervision of Reid Simmons at CMU (Simmons et al. 1997). The goal of the XAVIER research project is to develop autonomous mobile robots that can operate reliably over extended periods of time and can learn and adapt to their environments. Their video briefly describes the robot architecture, including obstacle avoidance, navigation, path planning, task planning, and the World Wide Web user interface.

Simmons has taken his robotic interests outdoors as well. Along with Mark Maimone and Dimi Apostolopoulos, Simmons developed NOMAD under the Lunar Rover Initiative Research Program (Wettergreen et al. 1999). A prototype for a moon-exploring robot, NOMAD stands 1.8-m tall and is 2.4- × 2.4-meters wide when its four wheels are fully deployed; the large robot is shown in figure 10. NOMAD has the ability to drive itself safely through unknown terrain using pairs of stereo cameras to detect obstacles. This ability was amply demonstrated during the summer of 1997 when NOMAD autonomously traversed 21 kilometers of the rocky, barren Atacama Desert of northern Chile during the 1997 Atacama Desert Trek. When not driving itself, NOMAD was teleoperated by satellite link from a public museum in Pittsburgh. In total, NOMAD traveled over 200 kilometers during the 6-week field trial, setting a new world record for field traverse by a planetary robotic explorer.

Teleoperation was also demonstrated on three other robots at the exhibit. IS Robotics presented URBAN ROBOT and ROAMS, and Real World Interfaces presented the MICRO-ATRV platform. The MICRO-ATRV is a small, rugged, four-wheel-drive mobile robot based on the ATRV-2 (figure 11), including the same reflex control architecture and software platform. The MICRO-ATRV is capable of traversing many types of outdoor terrain, including rocks, grass, sand, and concrete, as well as indoor terrain, such as carpet and tile. Many visitors to the exhibit hall enjoyed controlling the robot and terrorizing other visitors.

URBAN ROBOT is an indoor-outdoor robot with high mobility. Its invertible platform, housed in an impact-resistant shell, is equipped with tracked flippers that allow the robot to self-right; climb hills and stairs (figure 12); and stand upright to navigate narrow, twisting passages. Although URBAN ROBOT was initially designed to enhance the effectiveness of

Robot	Web Address
ATRV-2	www.rwii.com/
BABU and PI	arti.vub.ac.be/~paul/research.html
BEAST	ourworld.compuserve.com/homepages/laurent_chabin/insects.htm
CMTRIO	www.cs.cmu.edu/~robosoccer/
COG	www.ai.mit.edu/projects/cog/
JAVABOTS	www.cc.gatech.edu/~tucker/JavaBots/
KISMET	www.ai.mit.edu/projects/kismet/
KLUGE	www.cs.nwu.edu/groups/amrg/
MINDART	www.cs.umn.edu/Research/airvl/minirob.html
NOMAD	www.cs.cmu.edu/~lri/nav97.html
OFFICE PLANT #1	www.contrib.andrew.cmu.edu/~bohlen/plant1.html
PEPE	www.cc.gatech.edu/~ashwin/projects/pepe/
Robot Building Lab	kipr.org
SNIKY THE SNAKE	ourworld.compuserve.com/homepages/laurent_chabin/insects.htm
Sony PETS	www.cs.nwu.edu/groups/amrg/
THE SPIRIT OF BOLIVIA	www-robotics.usc.edu/~barry/ullanta
Stereo Perception	www.ai.sri.com/~konolige/svm/
STRIDE	www.isr.com/
TBMIN	www.cs.umn.edu/Research/airvl/minirob.html
URBAN ROBOT	www.isr.com/
XAVIER	www.cs.cmu.edu/~xavier/www/

Table 2. Participant Contact Information.

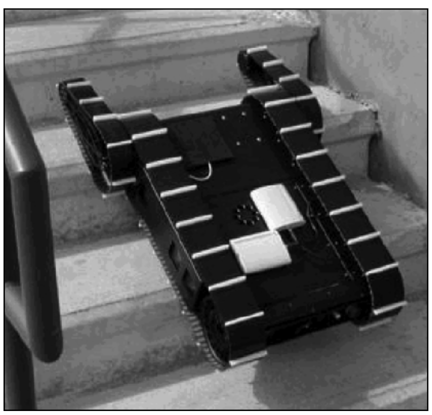

Figure 12. URBAN ROBOT.

mobile strike forces in urban terrain, its durability and versatility make it capable of joining the ranks of police officers, paramedics, and fire fighters as well as soldiers. Although many new control challenges are raised by URBAN ROBOT's innovative mobility mechanism, its durability allows for development of more ambitious navigation goals. Its ability to climb stairs also adds a dimension to the problem of mapping the robot's environment.

Although URBAN ROBOT is currently just a mobility platform, the next phase of development involves incorporating electronics and low-level control software into the platform.

ROAMS is a tracked vehicle with a pan-tilt camera, video transmitter, infrared sensors, and a radio for communicating with a base station. It is used as the mobile platform for a military project, STRIDE, that focuses on the interface between the robot and a person. The interface currently includes a voice-recognition system, joystick control, a head-mounted display showing the robot's viewpoint, and head and body trackers that allow the pan-tilt camera to mimic the motion of the user's head. The goal of the project is to combine intuitive control mechanisms and understandable data display with autonomous and semiautonomous robot behaviors to enhance the usefulness of the robot. The most successful control mechanism is a pan-tilt mechanism that can be used to remotely explore an area in a nondisorienting way as well as to point out a direction for further investigation. Data received from the robot are displayed as an overlay on the video image, and the information is condensed so that the user is not overloaded. The robot can also be sent off on its own using an autonomous hazard-avoidance behavior. More complex mission behaviors will be developed and integrated with the interface in the next phase of the project.

The final exhibit, the robot-building lab, was presented by David Miller, Cathryne Stein, and James Maybury from the KISS Institute for Practical Robotics. Two days prior to the start of the conference, approximately 35 AI researchers and graduate students (and one high school student) spent their time designing, building, and programming robots for the Fourth AAAI Robot Building Lab. The goal of this year's lab was to build autonomous mobile robots that play the game Black Ball in the Corner Pocket. The game involved navigating from one side of the playing surface to the other and moving Ping Pong balls into the goal area. Extra points were awarded for getting balls into a special scoring pocket, and even more points were awarded for scoring black balls. To make it more interesting, pairs of robots competed, playing simultaneously in opposite directions.

The 10 robots constructed during the lab used a variety of strategies to accomplish the task. Some navigated across the field by following a lighted beacon, others used line following, and still others used dead reckoning. Most robots tried to scoop up or bulldoze the balls into the scoring area. The robots were programmed in IC (a multitasking variant of C) and used a variety of behavioral programming techniques.

During the double-elimination tournament held Monday afternoon, there were a variety of exciting plays, but the final round came down to two unique robots: STOCHASTIC PLASTIC (nicknamed EVIL) and BEER. STOCHASTIC PLASTIC had three major subassemblies: First, it had a bulldozer blade at the front for pushing balls; second, it had a high-speed spinning mallet to shoot balls toward the goal; and third, for defense, it trailed a barrier of Legos, making it difficult for the other team to get balls into its scoring area. BEER was a much simpler robot; it was designed as a mobile oscillating fan. BEER literally blew the balls to the far end of the field. It was a close match, and when BEER first faced STOCHASTIC PLASTIC, it was defeated. STOCHASTIC PLASTIC successfully deployed its barrier, shutting out almost the entire scoring area from BEER, and prevailed in that round. In the final sudden-death round, however, BEER got off to a good start and blew many balls into the goal before the barrier was fully deployed; so, BEER triumphed over EVIL.

The exhibition is growing, both in terms of the number of presenters, the diversity and scope of the presentations, and the degree of audience participation (see tables 1 and 2 for a list of participants and their contacts). The demonstrations were frequently jammed with conference attendees; on the evening that the competition and exhibition were held in conjunction with a conference reception, the exhibit hall was literally filled to capacity. In addition to the demonstrations and presentations at the conference, the exhibition included a published video proceedings for the first time. The 69- minute video is composed of segments submitted by researchers and a compilation of shots from the conference (more information about the video can be found on the web at www.cs.cmu.edu/~aaai98/exhibition/video.html). Videotaped demonstrations have proven to be an effective means of presenting new research in robotics; we plan to continue offering this avenue in the future.

In closing, the AAAI Mobile Robot Competition and Exhibition provides a unique, first-person venue for demonstration and discussion of mobile robotics research. The flavor of the exhibition reflects leading-edge research in the community. The 1998 robot exhibition witnessed an interesting shift because a new focus of research is emerging: Many investigators are moving from the study of basic mobility and navigation to human interaction, multiagent challenges, and even entertainment. Thus, the exhibition is a vital component of the annual AAAI conference.

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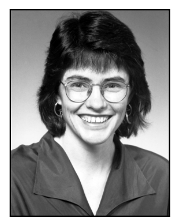

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