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The AAAI-2002 Robot Exhibition

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■ The AAAI-2002 Robot Exhibition offered robotics researchers a venue for live demonstrations of their current projects. Researchers ranging from undergraduates working on their own to large multilab groups demonstrated robots that performed tasks ranging from improvisational comedy to urban search and rescue. This article describes their entries.

The AAAI Robot Exhibition offers robotics researchers a venue for live demonstrations of their current projects and gives others an opportunity to see a selection of current research work. At the 2002 exhibition in Edmonton, Alberta, Canada, 12 robots were demonstrated by a variety of laboratories and institutions. Many of these systems were works in progress, providing the audience an opportunity to see snapshots of research programs in midphase. Contributors ranged from independent undergraduate projects to large multilab efforts.

Despite the range of robots and researchers, there were nonetheless a number of recurring themes worth noting. Robotic systems for urban search and rescue (USAR), an area of growing interest for several years, have continued to develop. Human-robot interaction is another dominant theme as researchers strive to build systems that can truly cooperate with humans. Multimodule systems, either in the form of robots that can reconfigure themselves by rearranging their own components or in distributed robot teams where the components are physically separate autonomous agents, are another popular area of research. Not surprisingly, many human-robot systems and multirobot systems are designed for USAR and other search tasks.

Another cluster of related themes we see is the use of robots in contexts such as hobbies, education, and entertainment, where in some sense the real goal of the system—whether the robot "realizes" it or not—is to make a change in the user, not in the world. Robot hardware design is of course also a common theme. Custom research robots are often dependent on the availability of cheap, versatile components that can be plugged together relatively easily without large investments in design or fabrication. Mainstays of the field, such as Legos, model-airplane servomotors, and the Massachusetts Institute of Technology (MIT) HANDY BOARD, are being augmented by new components, such as palmtop computers and the Carnegie Mellon University (CMU) CMUCAM, that provide considerably more sensing and computation than were previously available.

The remainder of this article provides, in alphabetical order, brief discussions of each of the entries based on text provided by their respective designers. The reader should assume that anything smart in the following pages is owed to the researchers, and anything incoherent is owed to poor editing on my part. It should also be mentioned that in the twenty-first century, we not only have the problem of what pronoun to use for individuals of unspecified gender (he, she, or they) but of what pronoun to use for robots (he, she, or it). Although different researchers have adopted different conventions, I have chosen to use *it* here for uniformity. I hope to see the day when the robots themselves will either confirm my choice or reject it.

ARMHANDONE

The ARMHANDONE (ARMANDONE) system from the Alcor Group in the Dipartimento di Informatica e Sistemistica, Universita di Roma "la Sapienza" is a custom-built mobile hand-eye

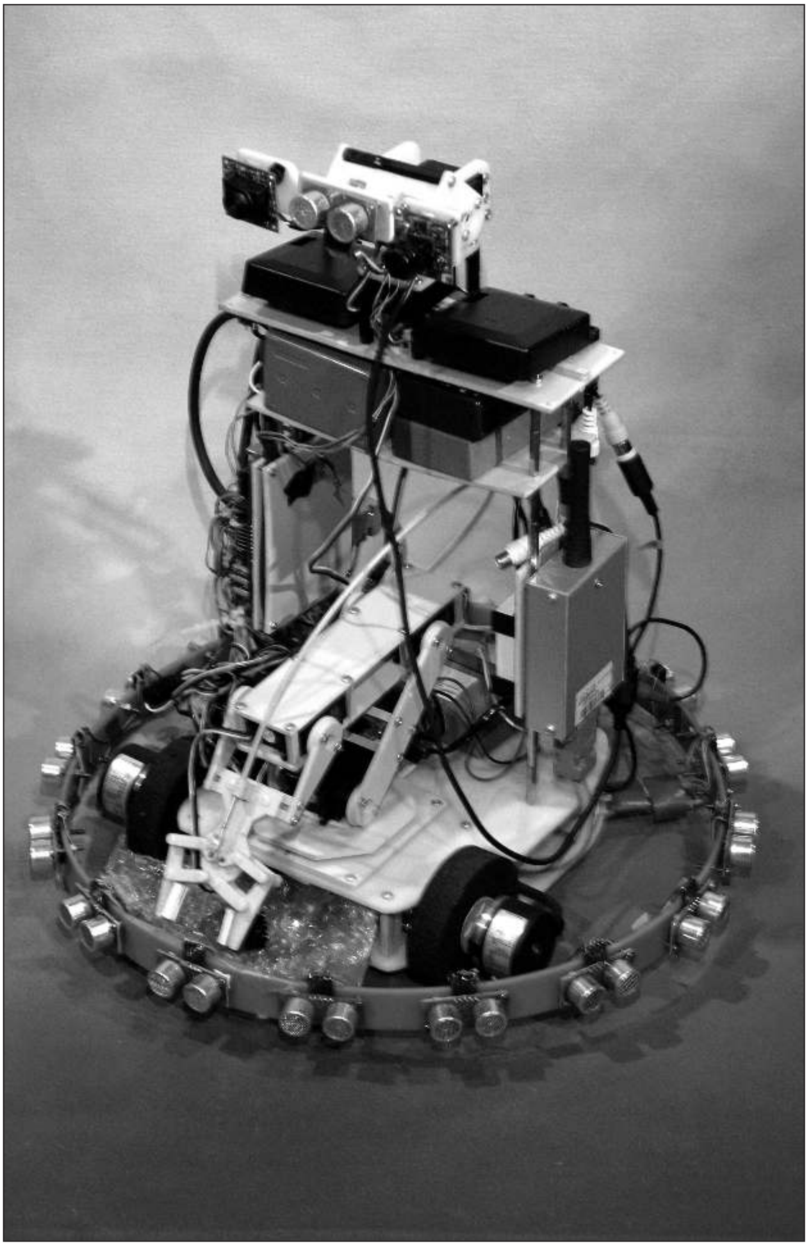

Figure 1. Universita di Roma's ArmHandOne Combines Stereo Vision, Manipulation, and Formal Reasoning.

system featuring a four–degree-of-freedom arm and an active stereo vision head on a two-wheeled differential drive base. Its control system uses a three-layered architecture that integrates cognitive and reactive control. The structural level interfaces with the robot's hardware. The reactive level is implement primitive, controls sensors, and builds a metric map of the environment. The cognitive level performs high-level reasoning and transforms the metric map into a topological map (figure 1).

At the exhibition, the robot moved through a rectilinear maze built from polystyrene sheets. The maze included an exit sign and optionally one or more small blocks that can be collected with the robot's gripper, depending on the task at hand. Starting from a random location, ARMANDONE searches for and recovers blocks and proceeds to the exit.

ARMANDONE starts by exploring the maze to find a block. If it finds the exit in the process, it stores the exit's coordinates and continues. If it finds a block first, it continues exploring until it finds the exit, collecting any other blocks it encounters in the process. In the process, it builds both a local metric map used for path following and a topological map for tracking what locations have already been visited. In addition, it builds a symbolic representation of the current state of affairs by fusing data from several sources and uses this representation to choose an exploration strategy. It uses a theorem prover to check the consistency of its state information and restarts from its initial position when consistency is lost.

The MR.ARMHANDONE project is funded by the Italian Space Agency (ASI). It was demonstrated by M. Cialente, A. Finzi, I. Mentuccia, F. Pirri, M. Pirrone, M. Romano, F. Savelli, and K. Vona

BLUE SWARM 3

Although not yet complete, Utah State University (represented by Dan Stormont) showed prototypes of its new generation of BLUE SWARM robots, BLUE SWARM 3 was designed to compete in the Urban Search and Rescue competition in the 2003 AAAI Robot Contest (figure 2).

Self-Reconfiguring Hardware

Two entries this year exhibited self-reconfiguring hardware: CONRO and CRYSTAL ROBOTS.

CONRO

A great deal of progress has been made in the last few years on the design of robots with self-reconfiguring hardware. Two such systems, the University of Southern California (USC) Information Sciences Institute CONRO (exhibited by Wei-Min Shen and Behnam Salemi) and the Dartmouth University CRYSTAL ROBOTS were demonstrated at the exhibition this year.

The CONRO system is ultimately intended to provide soldiers with a miniature robot for reconnaissance and search-and-identification tasks. By reconfiguring itself, the robot will be able to adjust to a variety of environments from urban areas to seashores. USC demonstrated an eight-module system that can be

Figure 2. Prototype Machine for Utah's BLUE SWARM 3.

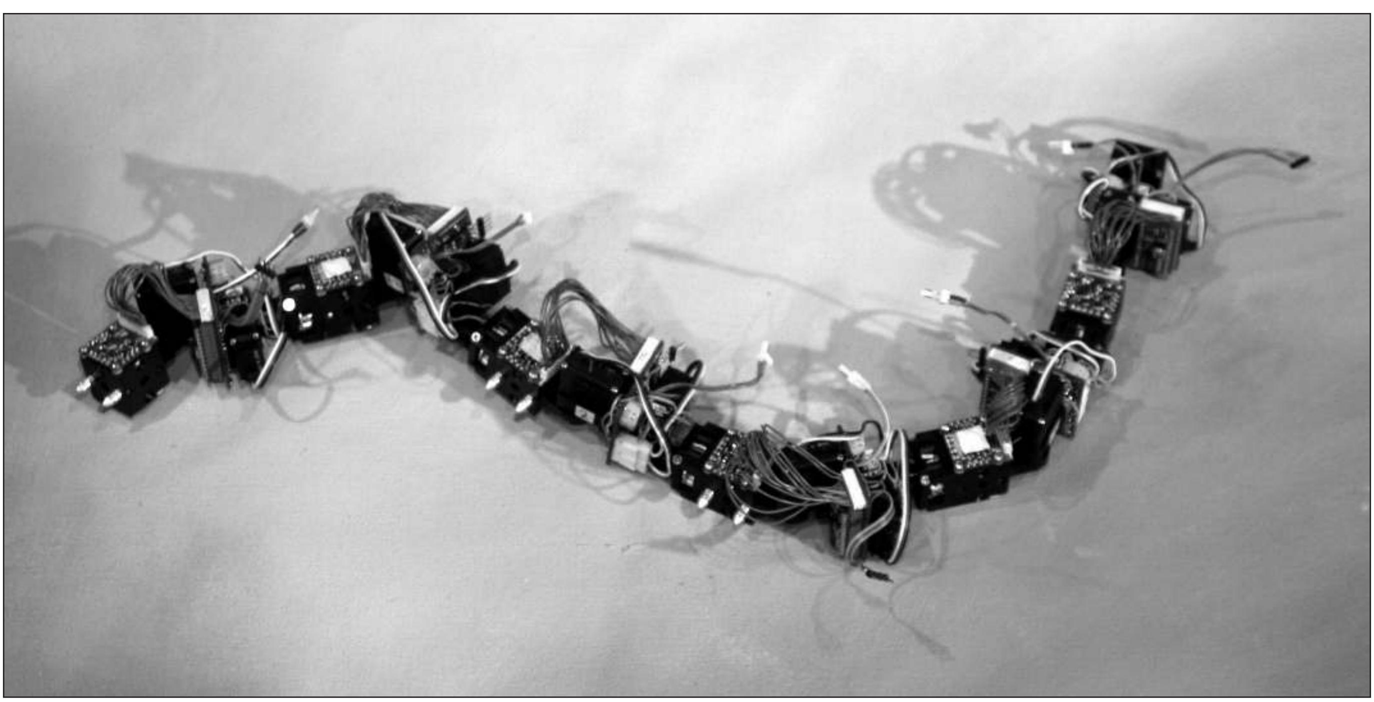

Figure 3. University of Southern California's CONRO in a Snake Configuration.

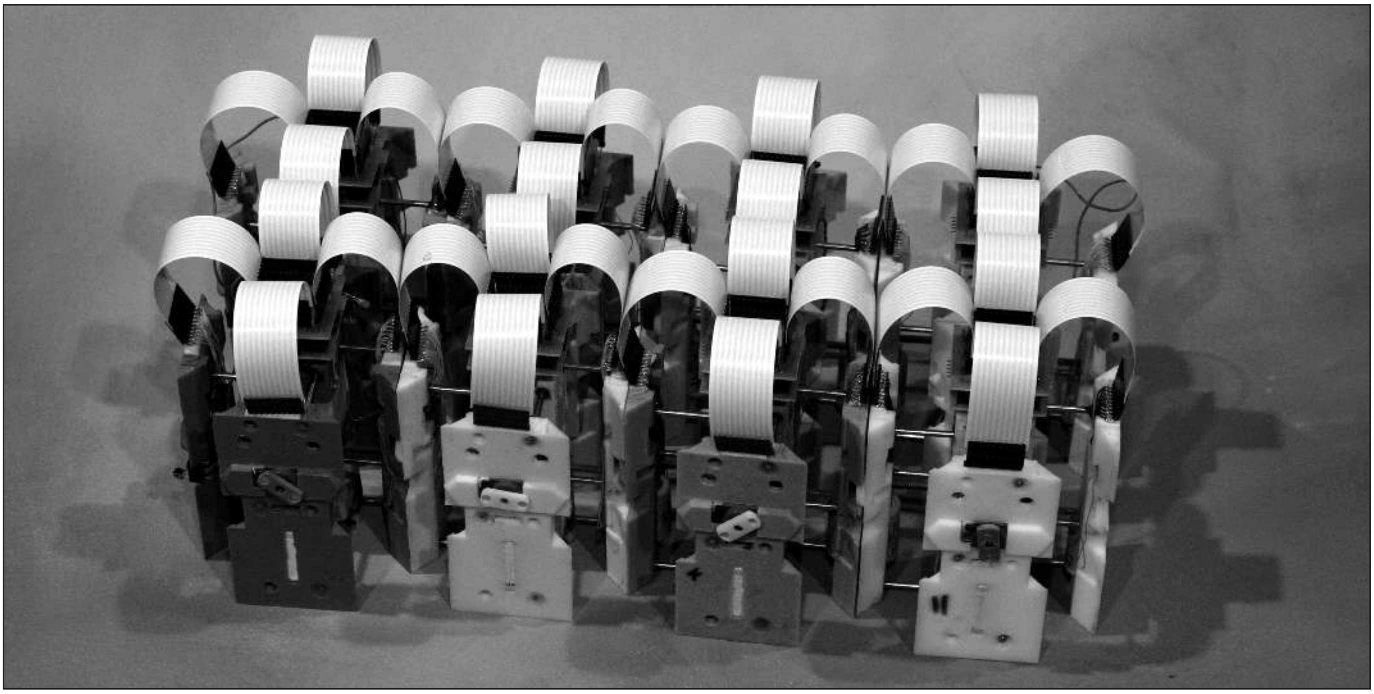

Figure 4. Dartmouth's CRYSTAL ROBOTS *Can Dynamically Rearrange Themselves in a Variety of Geometric Structures.*

Figure 5. University of Dallas Facial Expression Robot Is Built Using Techniques from the Special Effects Industry.

configured in a range of topologies. A simple linear topology allows snakelike motion, and more complicated topologies could allow legged motion (figure 3). Each identical module consists of a CPU, memory, battery, motor, and sensors. Designing the system involves a range of challenges from packaging, power, and cooling to programming and control

Crystal Robots

The Dartmouth Robotics Laboratory's CRYSTAL ROBOT system (exhibited by Robert Fitch and Daniela Rus) is another reconfigurable robot based on a collection of identical modules. However, their modules are designed to be laid out in a rectilinear crystal structure, like voxels in a three-dimensional display (figure 4). Their current system is capable of autonomous shape change, locomotion by self-reconfiguration, and self-replication of a big robot into smaller robots with the same functions.

It is ultimately intended to operate with hundreds of modules that autonomously organize and reorganize as geometric structures to best fit the terrain on which the robot has to move, the shape the object the robot has to manipulate, or the sensing needs for the given task. For example, the robot could synthesize a snake shape to travel through a narrow tunnel and then morph into a six-legged insect to navigate on rough terrain on exit.

Alternatively, they could use water-flow–like locomotion gaits in which the robots move by conforming to the shape of the terrain.

Identity Emulation, Facial-Expression Robot

Probably the most unusual of the robots at the Exhibition, the University of Texas at Dallas facial expression robot uses techniques from the Hollywood special-effects industry to construct a realistic, controllable humanlike face (figure

5). The system uses biomimetic structures, aesthetic design principles, and recent breakthroughs in elastomer materials to enact a sizable range of natural humanlike facial expressions.

This area is of increasing relevance to the AI community because of the growing body of work in emotion, personality, and social agents. Not surprisingly, the Texas team (represented by David Hanson, Marshall Thompson, and Giovanni Pioggia) is also working on a number of human-robot interaction systems, including human-form and facial-expression recognition and natural language interaction. They argue that the integration of mechanics, sociable intelligence, and design aesthetics will yield the most effective human-computer interface robots.

Kansa, Wichita, Coronado, and Pike

Distributed robotics, the use of teams of simple robots rather than individual complex robots, is another growing research area. Robot teams have advantages over individual robots in accomplishing goals that contain large numbers of subtasks. The advantage grows if they have the ability to interchange roles, share responsibility, or have redundant capabilities.

Kansas State's research aims to create a cooperative robotics reorganization model to dynamically evaluate and reorganize the team in the event of failure or other suboptimal condition (figure 6). They are building a model and system to allow a team of heterogeneous robots to conduct real-time reorganizations and work in multiple-task–environment domains.

They define an *organization* to be a group of robots acting in a specific role to accomplish a goal. The robots vary according to the physical and computational capabilities they naturally possess. Their capabilities reflect what role they can play in meeting a team goal. An organization will dynamically reorganize when the structure of the team changes, or the team members' capabilities change to create a suboptimal operating state. Kansas's robots continuously examine the capabilities and availability of each member and dynamically reorganize by swapping roles between team members to match changing task requirements with changing robot capabilities. The Kansas State University robots were exhibited by Eric Matson.

Figure 6. Kansas State's Robot Team Can Switch Roles between Members Dynamically.

Figure 7. Idaho National Engineering and Environmental Laboratory's David Bruemmer and JUNIOR Demonstrate Synergistic Human-Robot Interaction.

Junior

The Idaho National Engineering and Environmental Laboratory (INEEL), represented by

Figure 8. Minnesota's MinDART Is a Test Bed for Evaluating Distributed Robot Control Strategies.

David Bruemmer, demonstrated a robot for urban search and rescue (USAR) that can adjust its level of autonomy on the fly, leveraging its own intrinsic intelligence to exhibit levels of control from teleoperation to full autonomy. The robot is part of a project to develop new and innovative tools for synergistic interaction between autonomous robots and human operators and supervisors (figure 7).

The INEEL robot could actively protect itself and the environment as it navigated through the USAR environment. In addition, the robot continuously assessed and adapted to changes in its own perceptual capabilities. The robot's interface supported mixed-initiative interaction between the operator and human. It displays an abstracted representation of the robot's experience and exploits sensor suites and fusion algorithms for sensing, interpreting, and understanding environmental features.

INEEL's approach was motivated by operational experience working with robots in hazardous environments. They found that both teleoperated and fully autonomous approaches had weaknesses. Their approach is to use an architecture for dynamic autonomy control that permits the user to move between the two extremes. Sliding autonomy, as demonstrated in Edmonton in 2002, supports changing communication, cognitive, perceptual, and action capabilities of the user and robot.

For example, the robot's camera, which supports controllable pan, tilt, and zoom, can remotely be controlled by the user for inspection or can autonomously track people and objects. The robot can also autonomously follow a human even at high speeds. The robot is also equipped with a forward-looking infrared (FLIR) camera whose output can be combined with the output of the CCD camera to distinguish between living and dead people (or living and dead mannequins, in this case).

The robot also has a wide variety of ranging (sonar and laser) and proximity (infrared, bump switches) sensors to help the robot maneuver though terrain without colliding with objects, bumping its "head," falling down staircases, and so on. These sensors provide a field of protection around the robot and allow the operator to command the robot with full confidence.

MinDART

The Minnesota Distributed Autonomous Robot Team (MinDART), another distributed entry, is a group of simple and low-cost (Lego-based) robots used at the University of Minnesota Computer Science and Engineering Department for research into reactive control strategies (figure

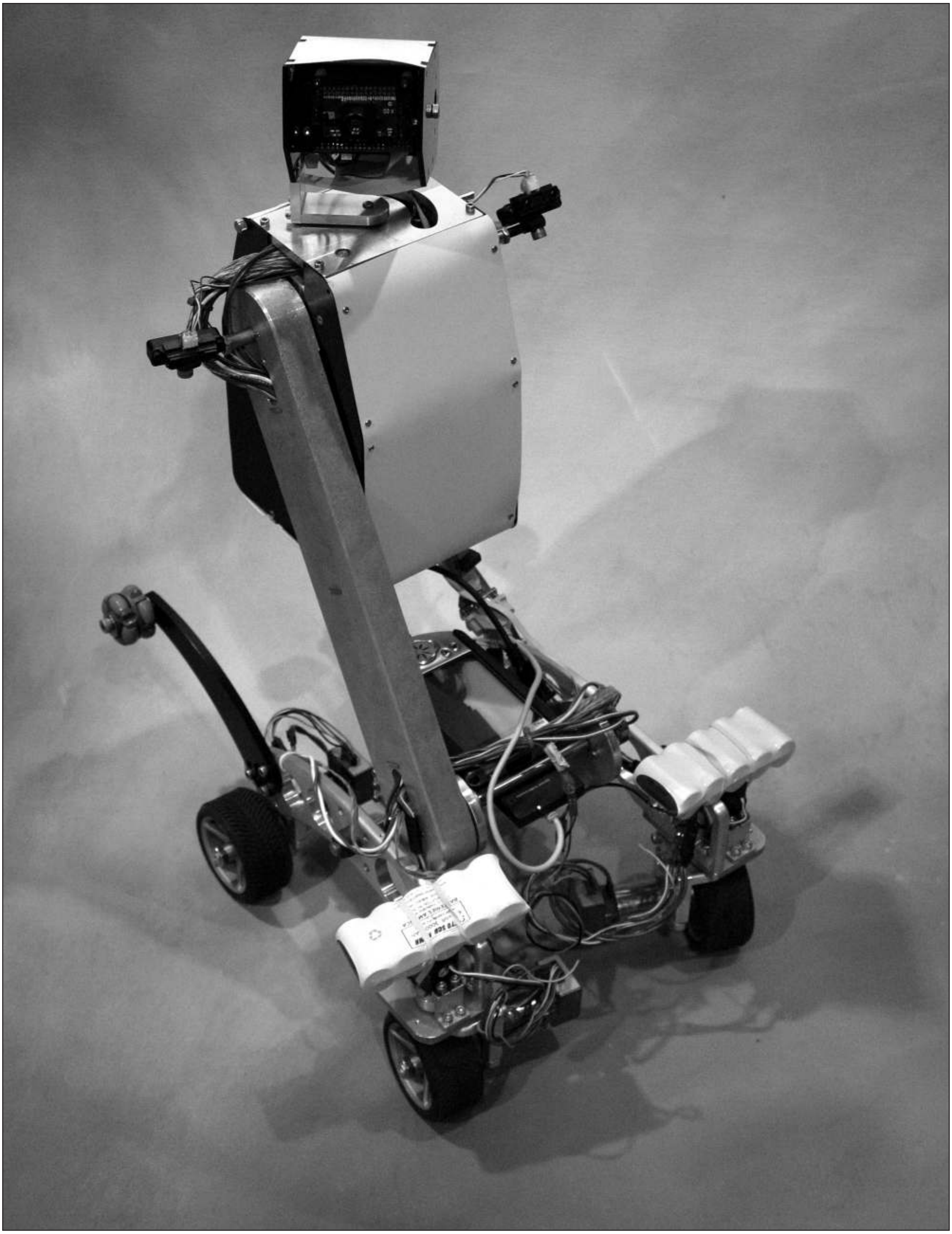

Figure 9. Carnegie Mellon University's PERSONAL ROVER*, a Prototype Domestic Robot.*

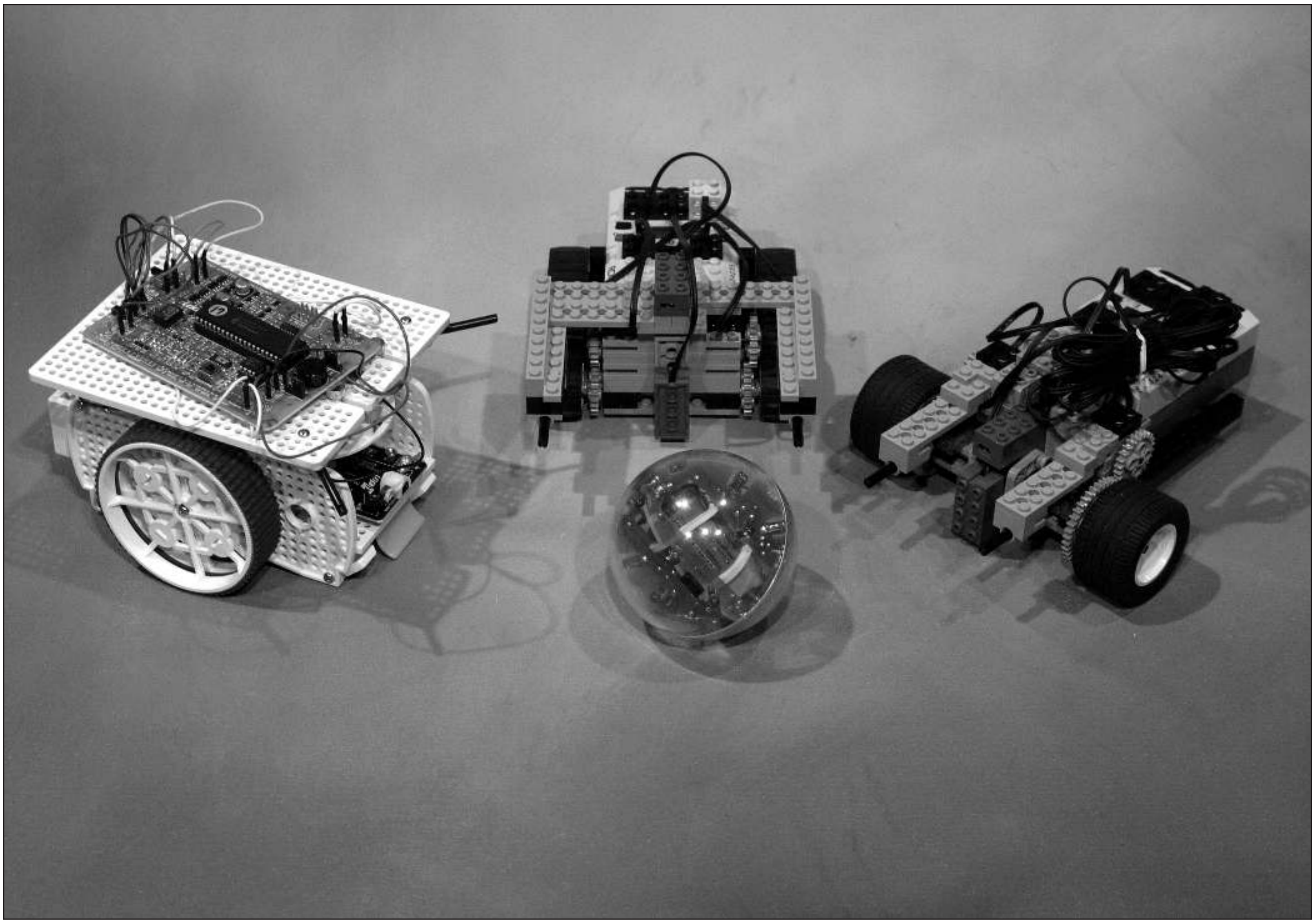

Figure 10. RoboCup Junior Is an Educational Initiative That Uses Robot Events to Motivate Students.

8). Minnesota researchers Paul E. Rybski, Maria Gini, and colleagues are interested in studying how environmental and control factors affect the performance of a homogeneous multirobot team doing a search-and-retrieval task. They have examined several factors affecting team performance. One factor is the distribution of targets, ranging from having a uniform distribution to having all the targets clustered together into one or two small clumps. Another factor they are examining is the size of the team (varying from one to five robots). Finally, the type of search strategy is varied between a completely reactive method to a directed search method that uses the robot's ability to localize itself.

The robots use CMUCAMS to localize themselves with respect to colored landmarks placed in the environment. By calculating the bearings of three colinear landmarks, the MINDART can resolve their global *x, y*, and ϕ coordinates in roughly five seconds. Alternatively, if the landmarks are not colinear, the MINDART can use an image-based homing algorithm to iteratively reduce the error between their current position and desired position. The robots also use the CMUCAM for kin recognition and implicit communication. When a robot detects the presence of a large number of targets, it can activate its light-bulb beacon to recruit the other robots that visually home in on the first one.

The HANDY BOARD is used as the robot's onboard computer, and all software is written in INTERACTIVE-C. The targets are infrared beacons that the robots can detect at approximately 70 centimeters.

Personal Rover

The PERSONAL ROVER project, exhibited by Illah Nourbakhsh of the CMU Robotics Institute, is a new approach for the dissemination of robotics technologies. In analogy to the personal computer movement of the early 1980s, its designers propose that a productive niche for robotic technologies is as a creative outlet for hu-

Figure 11. Northwestern's ROSEY *System Can Explain the Reasoning behind Its Own Actions.*

man expression and discovery. The PERSONAL ROVER itself is a prototype low-cost, highly competent personal robot for the domestic environment (figure 9). Like the MINDART system, it uses the CMUCAM to perceive landmarks. It also uses a mechanical design based on a swing-boom and rocker-bogie chassis that allows it to climb over large obstacles (as much as three times its wheel diameter). An IPAQ palmtop computer serves as a real-time control loop executor, and a wireless link allows it to be given tasks by a human and to take advantage of off-board processing. The robot can climb steps as well as avoid obstacles using vision.

RoboCup Junior

RoboCup Junior is a project-oriented educational initiative that sponsors local, regional, and international robotic events for students (figure 10). These events marked the third year of international competition, with a tournament being held in conjunction with RoboCup 2002. This year's Junior event included 65 teams of high school and middle school students from 16 countries around the world. Teams build and program autonomous mobile robots to play soccer, perform dances, and simulate rescue scenarios. RoboCup Junior has also been used as a theme for undergraduate classes in AI, robotics, and programming.

The RoboCup Junior organizer Elizabeth Sklar of Columbia University came to the exhibition to perform outreach to the American Association for Artificial Intelligence (AAAI) community. They are seeking mentors for teams of young students as well as educators looking for a new twist on standard undergraduate curricula.

ROSEY

ROSEY (robot self-explains why) from Northwestern University is a behavior-based robot that can explain its own behavior to a human user (figure 11). It was built in part to demonstrate that behavior-based robots can perform higher-level cognitive tasks. ROSEY was exhibited by Christopher Dac Le.

ROSEY generates explanations by inspecting its own internal reasoning structures. Like most behavior-based systems, its control system is essentially a circuit: Signals flow from sensors through wires and processing elements to the control input of the robot's effectors. This circuit structure captures the causal relations that exist between operators such as behaviors and plans and the sensory-motor conditions that drive them. ROSEY answers why questions ("why are you moving?") by tracing the circuit backwards from nodes to the input that drive them.

In the ROSEY demonstration at the exhibition, the user alternated between giving the robot high-level commands ("track green ball") and asking the robot about its motion and goals ("What are you doing?").

Information on the Web

You can find more information on these robots by visiting the exhibition web site,[1] which contains links to the web sites of the individual groups and their robots.

Note

1. www.cs.uml.edu/aaairobot/registered.html.

Acknowledgments

I would like to thank Christopher Dac Le for helping me organize the exhibition and the individual researchers for providing the text on which to base this article. Again, anything smart here is their doing, and anything incoherent is probably my doing. Le and I would both like to thank Holly Yanco and Tucker Balch for organizing the robot events as a whole and the AAAI staff for making the whole thing possible.

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