Newsletter of the IEEE Robotics & Automation Society

IEEE ROBOTICS AND AUTOMATION

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In This Issue

1990 IEEE INTERNATIONAL CONFERENCE ON

ROBOTICS AND AUTOMATION

Sponsored by the IEEE Robotics and Automation Society

General Chairperson: **R. A. Volz,** Texas A&M University
Program Chairperson: **A.J. Koivo,** Purdue University
Treasurer and Coordinator: **Harry Hayman**
Local Arrangements: **E.L. Hall,** University of Cincinnati

May 13-18, 1990
The Hyatt Regency Cincinnati
Cincinnati, Ohio

ADVANCE ANNOUNCEMENT
and
CALL FOR PAPERS

The theme of this conference is "Intelligent Automation and Robotics" with emphasis on information technology for sensor-based systems. Original basic and applied papers in all areas of automation and robotics are solicited. Special topics include but are not limited to the following:

- Automation systems: design, planning, modeling, evaluation, and optimization. Structural and geometric representation and reasoning.
- Flexible manufacturing systems: planning, scheduling, simulation and design for assembly.
- Artificial intelligence, knowledge management and expert systems for intelligent automation and robotics.
- Intelligent robot systems and their applications.
- Robot sensing: vision, touch, range, force. Information technology for sensors. Integration of multisensory information.
- Teleoperated and autonomous robots. Coordinated multiple robotic systems.
- Mobile robots: design, planning, navigation and applications.
- Micro electro-mechanical devices and systems.
- Applications of automation and robotics to industry, space, underwater, construction, medicine, hostile environment.

Submission of non-commercial papers from representatives of industry, universities, research institutions, and government is encouraged.

PAPER SUBMISSION: Four copies of papers should be sent by October 16, 1989 to:
A.J. Koivo, School of Electrical Engineering
Purdue University, West Lafayette, IN 47907

Reviews will be conducted by a program committee of established robotics researchers. Invited sessions will be entertained, but their papers will be reviewed by the normal process.
Authors will be notified of acceptance and furnished with an author's kit by January 15, 1990. Final papers received by the deadline will be included in the proceedings available at the conference.

The conference hosts workshops and tours on Sunday, May 13, and Friday, May 18, 1990, and tutorials on Monday, May 14. Conference sessions will be held on Tuesday, May 15 to Thursday, May 17, 1990. Prior to September 1, 1989 those with proposals for tutorials or workshops should contact: **Dr. J. Lin,** Department of Bioengineering, University of Illinois at Chicago, P.O. Box 4348, Chicago, IL 60680.

Announcing the Anton Philips Award for Best Student Paper

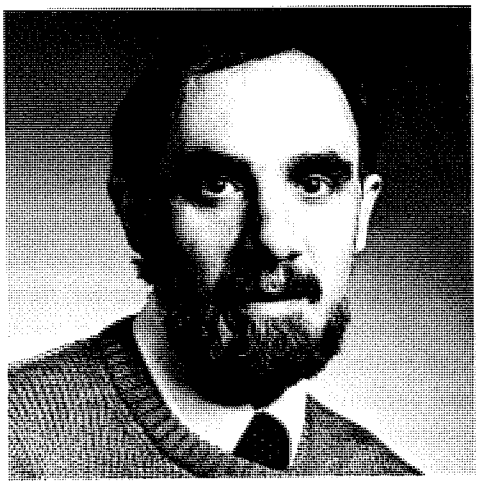
A $1000 prize will be awarded for the best paper offered by a graduate student. To be eligible, the student (1) must be first author and primary developer of the paper's ideas, (2) must have student status in June 1989 and (3) must be a member of the IEEE. Four copies of the paper, along with a nominating letter from the student's advisor and the student's IEEE membership number should be sent by October 16, 1989 to:

Anton Philips Award Committee
c/o A.J. Koivo, School of Electrical Engineering
Purdue University, West Lafayette, IN 47907

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.
IEEE

President's Message

Arthur C. Sanderson, President
IEEE Robotics and Automation Society



In recent years, the IEEE and its individual societies have played an increasing important role as a forum for the international exchange of technical information and the development of cooperative relationships among researchers and engineers in different countries. The IEEE membership throughout the world participates in both the publications and meetings of the technical societies as well as the many regional activities in individual Sections and Chapters.

Through a number of new initiatives, the IEEE Technical Activities Board is working to improve the level of participation and quality services offered to IEEE members internationally. Better international representation on Administrative Committees and IEEE Boards, the role of international offices in providing local support services, and the improvement in communication and dissemination of information through new technologies are being discussed.

One recent effort to improve international ties and cooperation within the IEEE was the Technical Activities Board meeting which was held this Fall in Singapore. This meeting brought together society presidents and division directors with regional officers from Asia. Associated with the TAB meeting in Singapore were a series of lectures and visits in India, Australia, and New Zealand. These visits provided the opportunity for technical seminars and discussions as well as exchange of information and comments on the role of the IEEE. I found the visits very informative and productive and they reemphasized to me the many different needs which IEEE fills throughout the world. I visited with robotics researchers at the National University of Singapore, the Nanyang Technological Institute in Singapore, as well as the Science Park, which encourages new entrepreneurial activities and startup companies. In India, I met with groups of enthusiastic students at several universities and institutes, I visited several excellent research laboratories exploring challenging problems in fundamental robotics research. In all of these cases, the IEEE provides an important link to rapidly changing technological developments in other parts of the world.

The Robotics and Automation Society already has a strong international membership which participates in publications and meetings. The opportunities for technical cooperation in our rapidly changing field are tremendous. At the same time, robotics and automation technology plays a key role in the competitive posture of both industries and governments. I would like to encourage active international participation in the Administrative Committee of the Society, the Editorial Board of the Journal, and the program committees of the annual conference. This year we are exploring opportunities to hold the annual conference outside of North America for the first time. We will keep you informed as this discussion progresses. We are taking steps this year to establish new chapters both in Europe and Japan. We would like to encourage your participation in these chapter activities as well as the development of other new chapters and new technical committees. Please contact Harry Stephanou, who is the Vice President for Membership and Chapter Development, and T.J. Tarn, who is the Vice President for Technical Activities, to explore these opportunities. Let me know if you have other suggestions or comments about the international activities of the society.

Reports from Research Institutes

Robotics Research at AFIT

Michael B. Leahy
United States Air Force Institute of Technology

The robotics systems laboratory at the Air Force Institute of Technology (AFIT) conducts research into the enabling technologies necessary for future Air Force robotic applications. The laboratory is a component of the Signal/Information Processing Laboratory and supports the interdisciplinary research initiatives of students and faculty from the Electrical and Computer Engineering and Aeronautics and Astronautics Departments. Laboratory support equipment includes: three DEC VAXstation III workstations, an ITEX CCD vision system, a PUMA-560, a JR3 wrist force sensor and an Utah/MIT dexterous hand. Two of the VAXstations are equipped with Avalon AP30 Vaccelerator boards. An environment has been created that allows a researcher to selectively enable or disable the original PUMA servo controller providing the flexibility to treat the robot as a black box or to perform experimental evaluations of modern control theory. A similar control system for the dexterous hand is under development.

Current robotics research efforts support the Robotics Telepresence and Robotic Aircraft Turnaround projects by conducting research on human arm emulation and robotic refueling. Human arm emulation studies are investigating intelligent control algorithms for gross and dexterous motion of manipulators with human-like kinematics. The requirement for intuitive operation on flightline equipment originally designed for human operators mandates the emphasis on anthropomorphic designs. Our initial objective is to develop and experimentally evaluate payload-invariant control algorithms. Past studies concentrated on experimental evaluation of model-based controllers. Those studies verified the ability of model-based control to improve the tracking accuracy of vertically articulated manipulators with high torque amplification drive systems. The Achilles' heel of model-based control is the need for accurate information about robot payload. For most flightline tasks payload variation will occur at the end-effector. Therefore current efforts are centered on developing a payload invariant form of model-based control. Techniques that employ neural nets and/or multiple model-adaptive estimators to estimate the payload dynamics and modify the feedforward compensation are under development. Replacing the standard PD feedback loop with more robust feedback controller based on the Quantitative Feedback Control technique is also under investigation. The basis of comparison between the algorithms will be experimental evaluations conducted on a PUMA-560. In-house techniques will also be compared to other techniques published in the literature. Initial results from our payload invariant research have been submitted for presentation at several conferences.

Dexterous fine motion research will examine the issue of degree of local autonomy for man in the loop operation of multifingered grippers. The test case will be a Utah/MIT hand on loan from the Armstrong Aerospace Medical Research Laboratory. Current piezoelectric tactile sensor research will provide the basis for development of the finger tip sensors necessary for compliant control evaluation.

The second major initiative is in improving the productivity of aerial and ground-based aircraft refueling. Refueling is a variation on the classic "peg in a hole" task. The standard refueling port is a cylindrical opening located at the end of a 30 degree slipway. The need to accomplish the task in a highly unstructured environment presents the largest challenge. Navigation to the worksite, although an important issue, is outside the scope of our current research. The plane is assumed to be within the workspace of the refueling manipulator. The goal is to demonstrate the ability to autonomously locate the port, visually servo the refueling nozzle onto the slipway, and then compliantly control the insertion. The PUMA has been equipped with a CCD camera in-

terfaced to a separate AP-30 equipped VAXstation III through an ITEX 100 board, and a JR3 force sensor. Software previously applied to face recognition is being modified to locate an aircraft aerial refueling port under realistic flightline lighting conditions. A form of impedance control is being hosted on the PUMA. Concept demonstration is scheduled for the spring.

Robotics is a small part of the overall AFIT research effort. Active efforts in the areas of automatic target recognition, speech processing, artificial neural nets, computer generated virtual environments and VHSIC technologies may all have an impact on our future efforts. For more information on our robotics research or other programs please contact Captain Michael B. Leahy Jr (513-255-9269) or Dr Curtis Spenny (513-255-3517). Internal laboratory reports and thesis copies are available upon request.

The Turing Institute

Contact: Eddie Grant, George House, 36 North Hanover Street, Glasgow G1 2AD, Scotland

The Turing Institute was established in 1983 as a not-for-profit company named in the honor of the late Alan M. Turing. It is dedicated to providing an environment for research, training, and development in the field of applied Artificial Intelligence (AI) accessible to both industrial clients and academic researchers. The Turing Institute is an academic affiliate of the University of Strathclyde.

Research at the Turing Institute is concentrated in the overlapping areas of expert systems, machine learning, computer vision, and advanced robotics.

- **Expert Systems** The Institute has developed expert systems for the selection of materials for valve-block manufacture, process control of industrial fluids and personnel allocation.

- **Computer Vision** The focus of the *image processing* group has been on image restoration and noise suppression techniques. The *industrial vision* group has concentrated on applications of computer vision in industrial inspection, quality control and medical diagnosis from computerized tomographic and magnetic resonance images, chromosome classification, vehicle recognition as well as several fixed and mobile robot projects.

The *advanced vision research* group has concentrated on developing techniques for the recovery of stereo, motion and color, along with their representation and integration in a common world model.

- **Advanced Robotics** The FREDDY 3 robotic environment contains two Puma robots and a wheeled mobile robot. These robots have multiple sensory systems including vision, tactile array-sensing, capacitative, inductive proximity/touch sensing as well as speech input and output.

In advanced robotics, the computer vision tools, machine learning techniques and PROLOG-based planning work are integrated to provide a powerful test-bed for research. The Institute has used a building block approach in which each new unit of work is available for succeeding developments to produce demonstrations of task co-operation, learning and rule-based sensory integration, collision avoidance, robot-robot and human-robot voice communication. *Current work* includes intelligent start-up and self-check of the robot environment and navigation of a mobile platform through a simple world using vision.

Reports from Research Institutes

RPI Brings Robotics to the Junior High

Sheila Nason
Rensselaer Polytechnic Institute

A fascinated group of eighth-grade students draws a design on a computer screen and then gathers to watch a computer-controlled mill inscribe this picture on a metal piece. When the milling operation is completed, a robot arm removes the piece from the mill and hands it to one of the students.

The CAD system, mill, and robot are part of a Technology Awareness Module funded by Rensselaer's Center for Advanced Technology (CAT) in Automation and Robotics. The module is being tested to see if it can help convince more students to choose careers in engineering and manufacturing.

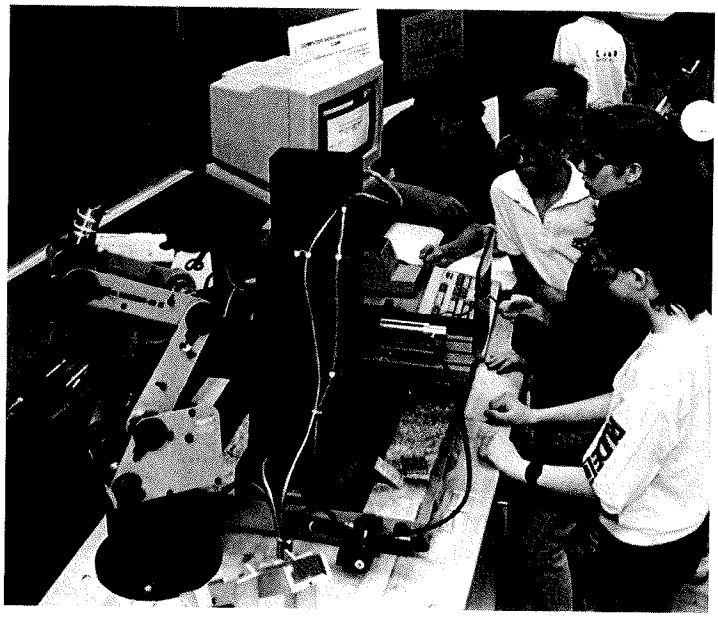
The Technology Awareness Module made its first appearance in October at Gowana and Koda junior high schools in Clifton Park, N.Y. During the 1989-90 school year, it also will be used in junior and senior high schools in Averill Park, Schenectady, Albany, and Troy, and will be used by more than 2,000 students.

By January, Raymond H. Puffer Jr., associate director of the CAT, hopes to convince industries to sponsor 10 more modules to be used during the 1990-91 school year in districts across New York State. Puffer said an industry can purchase a module for a school or a group of schools for about $30,000. Another $5,000 to $10,000 a year would be needed for training, support, and maintenance services.

"The modules offer exciting opportunities for companies to make an investment in the work force of the future," Puffer said.

The Technology Awareness Module was built and is being managed by Hudson Valley Community College, under the sponsorship of the CAT. As the program expands, faculty from other community colleges will be trained at Hudson Valley so the colleges can make the modules available to schools near them.

According to Douglas Baldry, associate dean of the School of Engineering and Industrial Technology at Hudson Valley, changes will be made in this year's prototype



based on lessons already learned. Additional equipm , such as a voice recognition or vision system might be added.

Puffer said the primary goal for the next modules will be to make them more compact and more rugged than the current model because of the need to move them from school to school.

The module is being tried this year in junior and senior high schools, but in the future, it will be aimed primarily at seventh- and eighth-grade students. Baldry said. The goal is to get these students excited about science and technology before they make high school course decisions.

Because all seventh- and eighth-grade students in New York are required to take a technology course, introducing the students to the manufacturing module at this level allows the program to reach students who might not otherwise consider engineering or technical careers,

including many women and minority students, Baldry said.

Rensselaer, Hudson Valley, and the New York State Education Department also are working on a high school program to take advantage of the excitement the module might inspire in eighth-graders. A sequence of courses, New York's equivalent of a high school major, in pre-engineering is being tested in several high schools, including Senendehowa.

Students there already are enrolled in *Digital Electronics* and *Principles of Engineering*, honors courses for the sophomore and junior years. The curriculum for the senior-level course, *Automation and Robotics* is being written this year, supported by CAT funding. The course will be tested at Shenendehowa during the 1990-91 school year and then offered to other high schools.

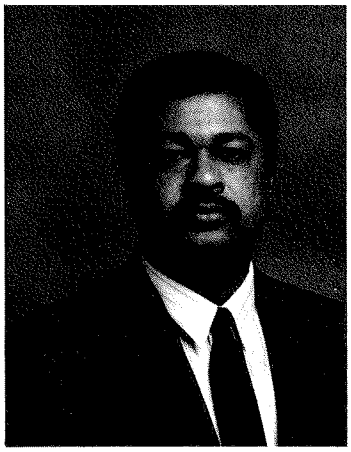
Michael Hacker, the associate for technology education for the New York State Education Department, noted that the pre-engineering sequence eventually will be made available to every high school in the state, giving students a far better understanding of the opportunities available in engineering before they make college decisions.

Delft Institute of Technology

Faculty of Electrical Engineering, Control Laboratory
Contact: G. Honderd and W. Jongkind. PO Box 5031, 2600 GA Delft, The Netherlands.

Research projects at the laboratory include:

- **The Delft Intelligent Assembly Cell (DIAC)** The DIAC project is sponsored by the Dutch Ministry of Economic Affairs. It was started at the end of 1989 and will run through 1991. This project involves research groups from four departments: Mechanical Engineering, Physics (Pattern Recognition Group), Electrical Engineering (Control Laboratory), and Mathematics and Computer Science. We are working on the development of a flexible assembly cell, in which two industrial robots will work together for the simultaneous assembly of a number of different products belonging to one product family. Research topics under this project include
  - systematics of assembly strategies
  - assembly cell programming techniques (operator interface)
  - collision-free path planning for two cooperating robots
  - sensor-based robot control
  - development of 1D, 2D, and 3D sensor systems
  - development of a sensor-controlled robot gripper.
- **The Mobile Robot** The purpose of this research project is to allow the mobile robot to function as an autonomous system. The robot must be able to interpret commands given by the operator (e.g., *go to location x* and plan its own movements accordingly, thereby depending upon an updatable environmental map stored in memory. Further, it must react properly to changes in the environment, either due to obstacles or to mapping inaccuracies.



Thomas Via of Fairfield, California has been recognized as a "leader of the future" by *Ebony Magazine.* The magazine spotlighted 30 young men and women nationwide who have excelled in business or professional pursuits by age 30 and have become involved in the business of giving back to their communities endless hours as advisors, mentors and volunteers.

Mr. Via is president of Via Technologies and is also an adjunct faculty member at Solano (California) Community College, a research member of Robotic Industries Association, a member , Computer and Automated Systems Association Technical Forum and Robotics International Technical Council of the Society of Manufacturing Engineers.

Reports from Conferences

Intelligent Robotic Systems: Design and Applications

Clint R. Bidlack, ChuXin Chen, and Suresh B. Marapane
The University of Tennessee

The workshop on Intelligent Robotic Systems: Design and Applications *was held in Philadelphia on November 7, 1989 in conjunction with the SPIE's 1989 Symposium on* Advances in Intelligent Robotics Systems. *The workshop was held in cooperation with the IEEE Computer and the IEEE Systems, Man and Cybernetics Societies. The workshop was organized and chaired by Mohan M. Trivedi of the University of Tennessee, Knoxville. For more information, contact the authors or Dr. Trivedi.*

The program consisted of nine presentations followed by a panel discussion titled *Accomplishments and Challenges in Developing Intelligent Robots.* The presentations were organized into three sessions: *Autonomous Navigation, Information Analysis: Languages, Models, and Algorithms*, and *Intelligent Robotic Systems.*

The panel discussion was moderated by Dr. Trivedi, and panelists included Peter K. Allen, Avinash C. Kak, Paul S. Schenker, Ramesh C. Jain, and Kitcha S. Ganapathy.

• Session 1. Autonomous Navigation
Chair: Martin Herman, National Institute of Standards and Technology

David Payton of Hughes Research Laboratories presented a reactive, real-time control architecture for autonomous outdoor navigation of mobile robots. The ALV (Autonomous Land Vehicle) system consists of two major modules: perception and planning.

The system is designed to satisfy all fundamental survival goals at the reactive level. High level plans are expressed in a form that allows them to be used to provide advice and information to the reactive control levels so that problems requiring opportunistic reaction to unexpected changes in the environment can be solved more easily. The ALV keeps contact with a radio tower; thus the path generated by the ALV's planning module must avoid RF shadows in the terrain. The planning and perception systems developed by Hughes guided the ALV over an approximately 600 meter cross-country course at a speed of 3km/hr. Hughes is also running experiments in a simulated environment using simulated laser range data.

Next, **Edward Riseman** of the University of Massachusetts described his work with Allen Hanson on autonomous navigation in a known environment as an integration of three sub-systems, namely, planning, perception, and action. The navigation strategy relies on model-based vision. The robot detects several landmarks from an image, usually objects like buildings, telephone poles, etc. It then attempts to match these landmarks to a 3-D model of the surrounding terrain. The robot can then keep track of its position within the 3-D model and plan its next move accordingly.

Concluding the presentations was **Martial Hebert** of Carnegie-Mellon University, who addressed recent progress on the CMU Navlab, along with the Planetary Exploration walking robots; the work done by himself and Eric Krotkov, Takeo Kanade, and Charles Thorpe. Hebert considers that robots are physical, problem-solving systems, and he argues that robot design needs to consider task-specific models, the explicitness of representations, and architectural support. He illustrated the concept using two example systems.

The first example came from NavLab. A comparison was made between CODGER and EDDIE, the communication and database systems. The CODGER was designed to be a general system, but suffers from architectural overkill and difficult system maintenance, while EDDIE, the replacement of CODGER. focuses on real issues of local vehicle navigation, high-speed lower level, and simplified, fast, point-to-point communications.

In the second example, he presented the design of a walking machine for planetary exploration on Mars, and showed that in an environment that requires high performance in terms of processing speed, difficulty of scenes,

and precision of output, specialized perception and architectures are inevitable and desirable.

• Session 2. Information Analysis: Languages, Models, and Algorithms
Chair: Terrance Boult, Columbia University

Thomas Speeter, AT&T Bell Laboratories, began the session by describing a programming language for the description and control of dextrous manipulation of the Utah/MIT dextrous hand. Because of the inherent complexity and depth of knowledge required to program the hand, and the need for an abstraction of manipulation process to help in planning and describing long manipulation sequences, *HPL (Hand Programming Language)* was created to allow the users to describe dextrous manipulation at a high level. The abstraction used to describe manipulation is based on motion primitives such as "open", "close", "pinch", "swing", etc.

Speeter argues that the concept of motion primitives is borrowed from physiological motor control, and that feedback is required for learning, error correction, and fine tuning, but refinement and playback of motor programs is clearly part of the physiological repertoire as well.

The second speaker in the session, **Ramesh Jain** of the University of Michigan, addressed issues on environment models and information assimilation. He proposes to use *Environment Models (EM)* to represent the state of an autonomous intelligent agent that combines perception, cognition, and action. The EM is the heart of his system and is responsible for interaction among different components, for providing temporal coherence, for combining information from multiple sensors, and for the purposeful behavior of the system.

Jain suggests that the combination of information from disparate sensors should be viewed as a problem in information assimilation, rather than sensor integration. He states that the focus in information assimilation is on the physical world being modeled, sensory information is just a means to the end, and that sensor integration treats the goal implicitly, misplacing the focus on the processing of sensed information.

Following Jain was **Jean-Claude Latombe** of Stanford University, who described work done by himself, J. Barraquand, and Bruno Langlois on numerical, potential field techniques for robot path planning. The principle of their approach to the path planning problem consists of a hierarchical, bit-map description of the objects, numerical computation of potential field over workspace without local minima, combination of workspace potentials, efficient systematic techniques for escaping local minima, and incremental construction of graphs connecting different local minima.

According to Latombe, using multi-scale pyramids of bit-map arrays for representing both the workspace and the configuration space of the robot allows efficient utilization of numerical, potential fields. He showed that these techniques in path planning are very fast and capable of handling systems with many degrees of freedom.

• Session 3: Intelligent Robotic Systems
Chair: Jean-Claude Latombe, Stanford University

Avinash Kak of Purdue University, the first speaker, discussed model-driven vision for object recognition and mobile robot navigation. In the vision system for 3D object recognition *(3D-POLY)*, the feature data are organized for the models using a data structure called the feature sphere, and local feature sets are used for hypothesis generation. The combination of the two results in a system whose time complexity has a low-order polynomial bound. Kak also presented a model-driven, mobile robot navigation system *(PSEIKI)* using the hierarchical evidence accumulation method. The Dempster-Shafer formalism is used for associating belief values with the different possible labels for the constructed abstraction in the perceived image.

Next, **Bir Bhanu**, of the Honeywell System and Research Center, presented details of proposed intelligent systems for air and land vehicles. He discussed a research project on obstacle detection during helicopter low-altitude flight. He stated that the results of the project could also be applied to autonomous safe landing on Mars. For land vehicles, Bhanu also described the ongoing research projects including dynamic scene understanding for motion detection, recognition, tracking and terrain interpretation, human engineered remote driving systems, and path planning and retrace navigation capabilities.

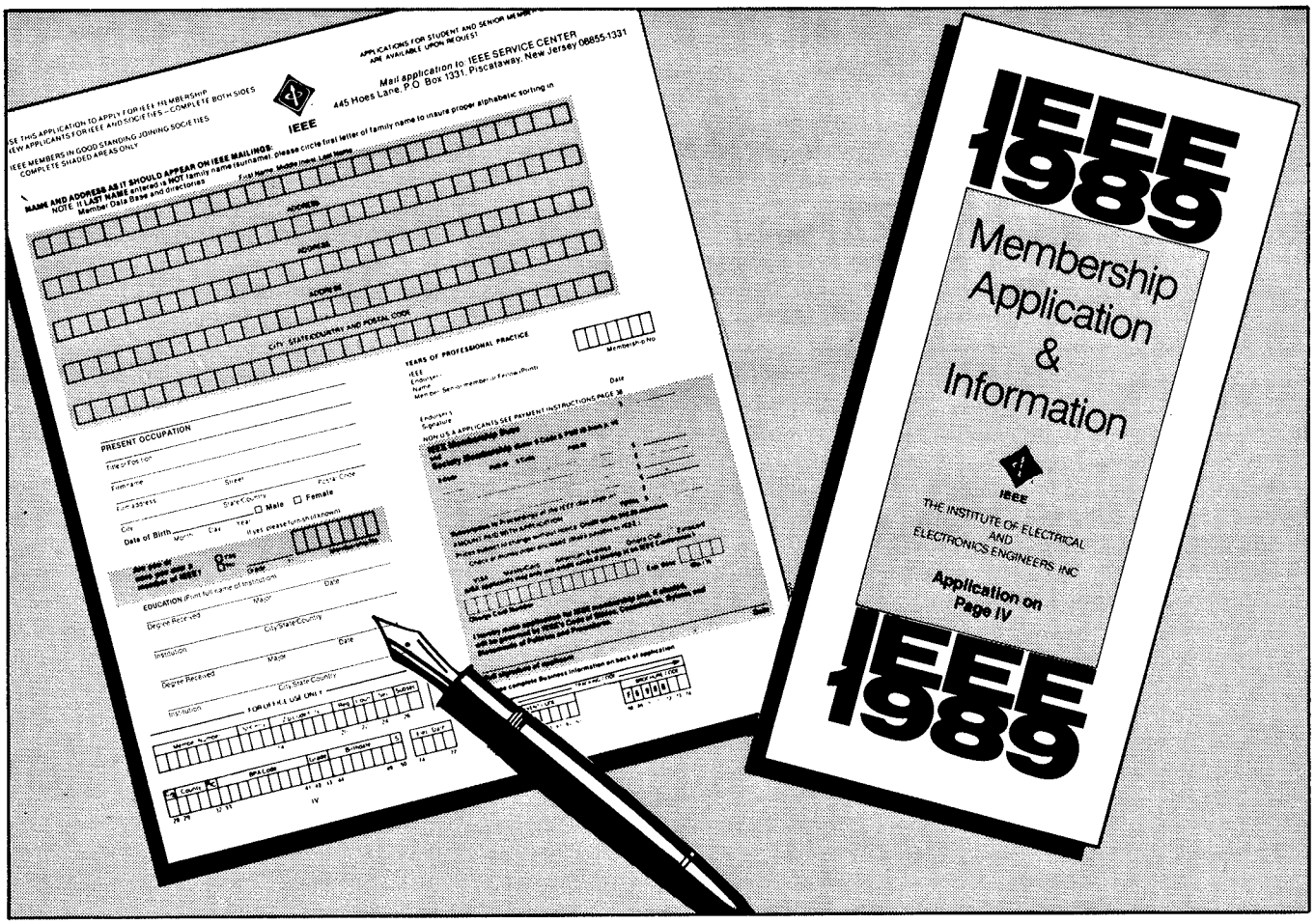
The last speaker in this session, **Brian Schmult** of AT&T Bell Laboratories, described a working, multi-robot system for automatic disassembly of Lego™ structures. The system can disassemble complex, Duplo™ from a simple object model. The emphasis is on a real system so as to locate and analyze the true nature of difficulties, as opposed to suspected prob-

Calendar

- **Jan. 29-31** First Australian Conference on Neural Networks. Sydney, AUSTRALIA. Sponsors: University of Sydney and others.
- **Feb. 12-14** IEEE Micro Electro Mechanical Systems Workshop. Napa Valley, CA. Sponsor: IEEE Robotics & Automation Society.
- **May 29-31** IEEE International Workshop on Advanced Motion Control. Yokohama Japan. *Contact:* Prof. Kouhei Ohnishi, Dept. Electrical Engineering, Keio University, 3-14-1 Hiyoshi, Kohoku, Yokohama, 223 Japan, Tel: 81-44-63-1141, FAX 81-44-63-3421.
- **April 16-20** Applications of Artificial Intelligence VIII. Orlando FL. Sponsors: SPIE in cooperation with IEEE Computer and Systems Man & Cybernetics Societies.
- **May 7-9** 40th IEEE Vehicular Technology Conference.Orlando, Florida. *Contact:* IEEE VTC '90, Winter Park PL 32790-1317, (407)-629-5712.
- **May 13-18** IEEE International Conference on Robotics & Automation. Cincinnati, Ohio. Sponsor: IEEE Robotics & Automation Society *See Announcement* .
- **May 21-23** International Conference on Computer Integrated Manufacturing. Troy NY. Sponsor: Rensselaer Polytechnic Inst., See *Calls for Papers.*
- **June 3-6** 3rd National Conference on Robotics. Melbourne AUSTRALIA. Australian Robot Association, *See Calls for Papers.*
- **June 21-22** IEEE International Workshop on Intelligent Robots and Systems. Tsuchiura JAPAN. *Contact:* Dr. Tatsuo Gotoh, Mechanical Engineering Research Laboratory, Hitachi Ltd., 502 Kandatsu-machi, Tsuchiura-shi, Ibaraki-ken, 300 JAPAN.
- **July 4-6** 1st International Conference on Automation Technology.Taipei Taiwan ROC. Sponsor: China Society of Industrial Automation & Automated Industries *Contact* Yung-Chun Wu, Control Engineering Dept., National Chiao Tung University, Hsinchu, Taiwan, ROC, Tel (035)712121 ext 2301, FAX (035)715544.
- **July 9-11** Japan-USA Symposium on Flexible Automation. Kyoto JAPAN. Sponsor: Instit. of Systems, Control, and Information Engineers and American Society of Mechanical Engineers, *Contact:* ISCE, Yoshida-Kawaharacho 14, Sakyoku, Kyoto 606 JAPAN, FAX 075-751-6037 *or* ASME, 345 47th St., New York, NY 10017.
- **July 18-20** 3rd International Symposium on Robotics & Manufacturing. Vancouver BC CANADA. Sponsor: Simon Fraser University, Burnaby BC CANADA *Contact:* Prof. AA Goldenberg, Dept. Mechanical Engineering, Robotics & Automation Laboratory, University of Toronto, Toronto CANADA.
- **August 9-11** IEEE International Conference on Systems Engineering. Pittsburgh, PA, USA. Sponsors: IEEE, Wright State University,& Carnegie Mellon University. *Contact:* Belle Shenoi (813 873 3527) or Pradeep Khosla (412 268 5090).
- **August 20-22** IEEE International Conference on Intelligent Motion Control. Istanbul TURKEY. *Contact* Prof. M. Okyay Kaynak, Dept. Electronic and Electrical Engineering.
- **Sept. 5-7** 5th IEEE Symposium on Intelligent Control. Philadelphia PA. Sponsor: IEEE Control Systems Society. *See Calls for Papers.*
- **Sept 18-21** International Conference on Automation, Robotics, and Computer Vision. Singapore. Sponsor: Nanyang Technological Institute. *See Calls for Papers.*

Newsletter Deadline

The Deadline for items to be included in the Spring issue of the newsletter is February 15. Submissions by e-mail (wes@ecelet.ncsu.edu) are appreciated, but should be accompanied by a hard copy via U.S. mail.



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IEEE Robotics & Automation Society

ROBOTICS AND AUTOMATION

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