Newsletter of the IEEE Robotics & Automation Society

ROBOTICS AND AUTOMATION

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THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.
IEEE

1991 IEEE INTERNATIONAL CONFERENCE ON

ROBOTICS AND AUTOMATION

Sponsored by the IEEE Robotics and Automation Society

General Chairperson:	**T.C.Hsia,** University of California, Davis
Program Chairperson:	**T.J. Tarn,** Washington University
Program Vice-Chairpersons:	**Katsuhisa Furuta,** Tokyo Institute of Technology
	Randy Phillips, G.E. Corporation
	Harry E. Stephanou, George Mason University
Treasurer and Coordinator:	**Harry Hayman**
Local Arrangements:	**Doug Boone,** Hewlett Packard

April 7-12, 1991
Hyatt Regency Sacramento
Sacramento, California

CALL FOR PAPERS

The theme of this conference is "Automation and Manufacturing in the 90's" 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 September 16, 1990 to:

T.J. Tarn, Systems Science and Mathematics
Campus Box 1040, Washington University,
St. Louis, MO 63130

Reviews will be conducted by a program committee of established researchers. The program committee is also soliciting proposals for invited sessions. The program committee particularly encourages cohesive sessions focusing on new emerging areas and sessions created around theme problems. Such sessions proposals will have priority over those of a classical or mainstream flavor. Proposals should be submitted by September 16, 1990, to the program chairperson, Professor T.J. Tarn.

Authors will be notified of acceptance and furnished with an author's kit by January 3, 1991. Final papers received by the deadline will be included in the proceedings available at the conference.

The conference hosts workshops and tours on Sunday, April 7, and Friday, April 12, 1991, and tutorials on Monday, April 8. Conference sessions will be held on Tuesday, April 9 to Thursday, April 11, 1991. Prior to September 1, 1990 those with proposals for tutorials or workshops should contact: Dr. H. Stephanou, Department of Electrical & Computer Engineering, George Mason University, Fairfax, VA 22030.

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 1990 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 September 16, 1990 to:

Anton Philips Award Committee
c/o **T.J. Tarn,** Systems Science and Mathematics
Campus Box 1040, Washington University,
St. Louis, MO 63130

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.
IEEE

From the President

Arthur C. Sanderson
Rensselaer Polytechnic Institute

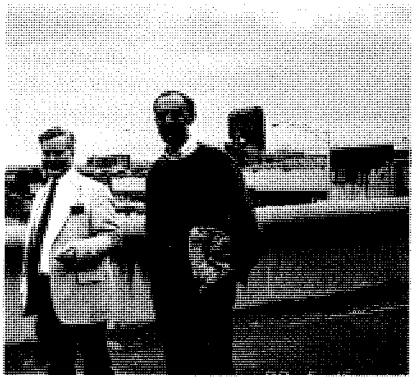
Our recent Annual Conference in Cincinnati was the seventh IEEE International Conference on Robotics and Automation. The Conference continues to be a major forum for exchange of the latest technical results in Robotics and Automation research as well as an opportunity to exchange views and ideas in a relaxed setting. This year we had over 778 attendees at the Conference from over 23 different countries. The scope and depth of the technical presentations continues to evolve and represents both a maturing of the field and an exploration of new ideas and issues.

An important trend has been the development of well-characterized experimental methods for validation and evaluation of theoretical approaches to kinematics, dynamics, and control. With increased emphasis on redundant manipulators, multiple manipulators, flexibility, compliance, and force control, these methods add to our understanding of the real systems issues and the impact of alternative technical approaches. The increased importance of these experimental results ties closely into the increased use of video to present results more effectively at the Conference. In conjunction with next year's Conference in Sacramento, we plan to make selected videos available as a collection of video conference proceedings.

Many specific technical topics have matured in their approach and methods of formal analysis. Algorithmic path planning for robot arms, motion planning, and navigation for mobile robots, sensor fusion and three-dimensional reconstruction and characterization of uncertain and dynamic environments are examples of formal methods and problems which were often handled heuristically in the past.

In addition, the breadth of technical topics and applications continues to grow in Robotics and Automation. Approaches which address adaptive and learning techniques, including neural networks, issues in software and architectures, and the development of new actuator and sensor technologies, including micromechanical devices, offer exciting new directions. New applications and a refinement of needs and goals for familiar areas have led to continued progress in space, undersea, hazardous environments, and service applications. The banquet speaker at the Conference described the extensive work on undersea robotics carried out by the Woods Hole team, including discovery and exploration of the Titanic.

The plenary speakers at the Conference touched on various aspects of manufacturing automation. They discussed the increased recognition by industry that implementing and integrating automation systems to improve productivity, reliability, and flexibility requires strong efforts in organization and management as well as technology. While many companies continue this development of management and technical infrastructure concurrently, some have emphasized organization change at the expense of long-term investment in technologies required for advanced automation capabilities. A continued understanding of the need for fundamental advances in technology to meet the long-term demands for a competitive manufacturing position is an important element of industrial strategy.



President Sanderson and Dr. Robert Kelley of RPI en route to the Ohio Riverboat Cruise sponsored by the Conference.

If you did not have an opportunity to attend the Robotics and Automation Conference this year, I encourage you to read the Proceedings, which provide an up-to-date overview of new results, and I invite you to attend and participate in the Conference next year in Sacramento.

Thanks!!

Ernie Hall
University of Kentucky
1990 Local Arrangements Chair

At the recent 1990 International Conference on Robotics and Automation in Cincinnati, which had approximately 800 attendees, many informative and interesting interactions occurred. The best joke I heard was *Q. What happens if you ask 10 engineers to form a firing squad? A. They form a circle and shoot each other.*

Our recent meeting, on the contrary, was marked by a most wonderful spirit of cooperation. I would like to give special thanks to all the members of the local arrangements committee both for showing such hospitality to our national and international guests and for their patience and careful attention to detail.

Ms. Joan McLean spent a large amount of her time during the previous year assisting Dick Volz, Antti Koivo, Harry Hayman and our committee with the local arrangements which included local tours, a special riverboat dinner cruise, the conference reception and banquet and even a Cincinnati Reds-St. Louis Cardinals baseball game. She also coordinated the Hospitality Desk during the meeting with the assistance of **Pat Cox, Lori Mayes, and Shirley Freeman** from UC and the special organizational skills of **Juanita Graves** from UK.

They also assisted our student coordinators **Dan Repperger and Jim Graham** in directing the student assistants and our A/V specialist, **Walt Nolte,** in keeping all the equipment safe and operating.

We would like to give special thanks to **Ed Markowitz and John Pfeiffer** of the Institute of Advanced Manufacturing Sciences for making signs for the more than 80 technical sessions and other events.

This event was also a great opportunity for cooperation among the engineers from our local universities including Purdue, Ohio State, Kentucky, Northern Kentucky, Wright State, the Air Force Institute of Technology, Indianapolis, Miami, and Cincinnati. This was a rare occasion for normally competitive institutions.

We would also like to thank the more than 65 student volunteers who helped unpack the three-volume proceedings, and assisted with audio/visual and many other tasks at the meetings.

Special recognition goes to **Brian Swearingin** and the local IEEE student chapter for the design and production of the T-shirts given with registration to the student volunteers and sold to conference attendees.

Our artist **Michelle** came up with a most creative design of the Cincinnati skyline and a female next to a robot.

From the Editor

Wes Snyder

This is an exciting summer for me. I am turning over the reins of the newsletter to another editor, and taking a new job as well. It is with a mixture of sadness and relief that I turn over the editorship of this newsletter to **Dr. Michael Leahy,** who will assume the role of editor, beginning with the next issue. Mike received his Ph.D. in 1986 from Rensselaer Polytechnic Institute. He is currently a captain in the U.S. Air Force and is an assistant professor at the Air Force Institute of Technology and director of the Robotics Research Lab at AFIT. He may be reached at AFIT/ENG, W-P AFB OHIO 45433, Ph. 513-255-9629, e-mail: mleahy@blackbird.afit.af.mil.

The editorship has provided me the opportunity to work with some fine people, and these interactions have been very pleasant experiences for me, as I know they will be for Mike.

Rosalyn Snyder will remain as managing editor of the Newsletter, and submissions may still be submitted to her, at the address on the masthead.

I am also moving from North Carolina State University to Wake Forest University. At Wake Forest, I will hold a split appointment in the Computer Science Department, and in the Radiology Department of the Bowman Gray School of Medicine. I will still be doing the Image Analysis Research I have always done, but on medical, rather than industrial, images. I have been at NCSU for 14 years now, and it is with considerable sadness that I make the move, but yet, the new opportunities are truly exciting.

At the Cincinnati conference, I had the pleasure of hearing an inspiring talk by Dr. Kaneyuki Kurokawa of Fujitsu. That presentation is printed in its entirety in this issue of the newsletter. Dr. Kurokawa addresses the question of *what is wrong with American manufacturing,* and surprisingly, suggests that Japanese manufacturing may be on the verge of precisely the same problem(s). The paper implies that the work ethic is at the root of the issue. When young people grow up with their personal lives and economies devastated by war or depression, they develop a respect for hard work and therefore for productivity which leads, in thirty years, to a country which leads the world in manufacturing.

Dr. Kurokawa says he doesn't know what to do about the 30 year law, and neither do I. Certainly creating a depression doesn't seem like a good way to stimulate a work ethic.

One final remark Dr. Kurokawa made that struck a cord with me was his analysis of technology transfer. He proposed that Research and Development HAD to be together to be successful; not just philosophically,

("Wes Snyder, Cont. on page 4)

Society News

AdCom Election Results

Mr. Norman Caplan, will succeed Dr. Arthur Sanderson as President of the IEEE Robotics & Automation Society in January 1991. Mr. Caplan is a Senior Staff Associate with the National Science Foundation.

The AdCom elected **Dr. T.J. Tarn** to succeed Mr. Caplan as President-Elect in 1991. Dr. Tarn, who is at Washington University, is currently chairman of the Society's Technical Activities Committee and is Program Chairman for the 1991 Conference.

According to the Constitution, AdCom members will be elected to serve for 3 year terms. However, initially, the 18 AdCom members were chosen at random to serve one, two-, and three-year terms so that elections will be staggered. The membership at large received ballots to elect the six persons to fill three year terms ending 1992. They are:

Dr. Antal K. Bejczy, Jet Propulsion Laboratory, MS 198-330, California Institute Of Technology, 4800 Oak Grove Drive Pasadena, Ca 91109 Phone: (818) 354-4568.

Professor Alan A. Desrochers, Electrical, Computer and Systems Engineering Department Rensselaer Polytechnic Institute, Troy, NY 12180-3590 Phone: (518) 276-6718.

Professor Takeo Kanade, The Robotics Institute and Computer Science Department, Carnegie Mellon University, Pittsburgh, Pa 15213-3890

Professor John Y. S. Luh, Department of Electrical and Computer Engineering, Clemson University Clemson, SC 29631 Phone: (803) 656-5926
E-Mail: luhj@prism.clemson.edu

Professor Vladimir J. Lumelsky Department of Electrical Engineering Yale University, New Haven CT 06520 Phone: (203) 432-4249
E-Mail: lumelsky@cs.yale.edu

Professor George N. Saridis, Electrical, Computer and Systems Engineering Department Rensselaer Polytechnic Institute, Troy, NY 12180-3590 Phone: (518) 276-6076
E-Mail: saridis@ral.rpi.edu.

AdCom Committees-Meetings.

Dr. Steve Hsia, Chairman

The Meetings Committee has agreed that the IEEE Robotics & Automation Society should be a co-operating organization for two conferences: International Symposium on Intelligent Robotics, Jan. 3-5 or 7-9, Bangalore, India, M. Vidyasagar, General Chairman; and '91 ICAR: Fifth International Conference on Advanced Robotics -- "Robotics in Unstructured Enviroments", June 20-22, 1991, Pisa Italy, Conference Chair, Paolo Dario. *(cont. on page 5)*

The designation "in cooperaton with" means that the sponsors may use the name of the Society in advertising the conferences, but the Society does not have the financial interest or responsibility associated with sponsorship.

The R&A Society sponsors the **IEEE Workshops on Micro Electro Mechanical Systems (MEMS).** The following information is available for upcoming MEMS workshops:

MEMS '91: Nara Japan, Jan. 30-Feb. 2, 1991, General Co-chairs: Jiroyuki Fujita and Masayoshi Esashi.

MEMS '92 Berlin Germany, Mid Jan. or early March. General Co-chairs Wolfgang Benecke and Jan Fluitman.

MEMS-93: Location and time not yet decided. General Co-chairs, Jeffrey Lang and Albert Pisano.

Introducing...Norm Caplan

Norman Caplan, President-Elect of the IEEE Robotics and Automation Society is currently in the Division of Engineering Infrastructure Development of the National Science Foundation. He has been with the NSF since 1973 and has served as Program Director, Deputy Division Director and Acting Division Director, Electrical, Computer and Systems Engineering.

He previously served in the Research Division at New York University and as Adjunct Associate Professor of Electrical Engineering. After several assignments in industry, he rose to the position of Chief Engineer with Tracor's Systems and Sciences Division He is a member of Eta Kappa Nu and IEEE.

During his tenure at NSF, Mr. Caplan has been active in promoting robotics research. He was the Chairman of the Foundation's Coordinating Committee for Research in Intelligent Robotics Systems and is the United States representative to the international working group on advanced robotics of the IEEE.. *(Cont. on page 4)*

Introducing. . .TJ Tarn '91 President-Elect

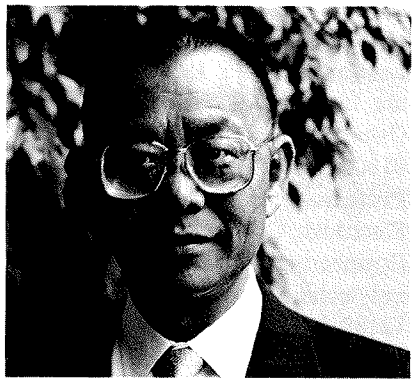
At the May meeting of the R&A Society AdCom Professor Tzyh-Jong Tarn of Washington University was elected as President Elect of the Society. He will become president in January 1992.

Tzyh-Jong Tarn has been at Washington University, St. Louis, since 1968. His is currently Professor of Systems Science and Mathematics. In 1987 he was appointed as the Director of the Center for Robotics and Automation at Washington University. He holds the title of Honorary Professor at several Chinese universities, including Tsinghua University. He has also held visiting positions at Imperial College, the University of Rome, Nagoya University, the Ecole Nationale Superieure de Mecanique in Nantes, and the Academy of Sciences of the USSR. He has published over 100 papers, including over 30 papers on dynamic modeling and control of robotic systems.

He serves as a Consulting Editor of the *Journal of Control Theory and Applications,* and Associate Editor of the *Series on Systems and Control: Foundations and Applications*, and as a member of the editorial board of the *Journal of Mathematical and Computer Modeling*.

Dr. Tarn was Local Arrangements Chairman of the 1985 IEEE International Conference on Robotics and Automation, and a member of the Program Committees for the 1987, 1988, and 1990 Conferences. He is Program Chairman of the 1991 Conference.

He was Chairman of the Society's Technical Committee on Robot Dynamics and Control in 1988 and is currently Vice President for Technical Activities. Since 1988 he



has served as a Technical Editor for the *Transactions on Robotics and Automation*. He is also a fellow of the IEEE.

Caplan on the future of the R&A Society *(cont. from p.3)*

As the R&A Society matures, it is important that we make an effort to look for activities which will involve industries, government, and universities in Robotics & Automation research and development. We need to look at the socio-economic impact of this technology and ways to educate and re-educate people to work with it.

I see a societal need for robotics in hazardous areas such as nuclear plants, mines, undersea, space, and certain manufacturing environments. The huge long-term investment necessary to accomplish the large scale development and implementation of these systems will require government action both to encourage research and to facilitate university/industry cooperation.

The research community is becoming increasingly multi-national. This is evidenced by programs such as EUREKA and ESPRIT, which require multinational European participation, and the Japanese MITI program, which is designed to encourage technological development around the world as well as in Japan.

It is important that the IEEE R&A Society encourage increased international participation not only in conferences but in society activities that contribute to the quality of life for all peoples.

From the Editor (Continued)

together, *physically* together. Universities and Industries simply MUST get their mutual acts together and make this technology transfer thing happen

Industries are saying now that they are on hard financial times, that they have difficulty justifying pouring money into university research programs. I have alwways maintain that they cannot afford NOT to support those university programs. At the same time, the universities cannot afford NOT to do some development, as well as research. They must go hand in hand, with the *same* people involved in both. It is somewhat satisfying to see a world-renowned authority (apparently) agreeing with me.

Productivity, then, is a complex issue-- it is first and foremost a societal issue. We must somehow instill pride in accomplishment,. Secondarily, it is a management and educational problem; and *that* aspect we can address. And (regrettably only third) it is a technical problem, one on which we technologists are making substantial progress.

That's what it will take to make productivity happen.

Highlights of the Cincinnati Conference

Robots and factories of the future and U.S. industry today were topics of interest at the **IEEE International Conference on Robotics and Automation** which took place in Cincinnati May 13-18.

More than 700 of the leading engineers and scientists from 23 countries met to discuss their research findings, which included the design of robots for space, manufacturing, and underwater applications.

The conference is sponsored by the **IEEE Robotics and Automation Society.** Prof. Richard A. Volz was General Chairman, Prof. A.J. Koivo was Technical Program Chairman, and Prof. Ernie Hall was Local Arrangements Chairman.

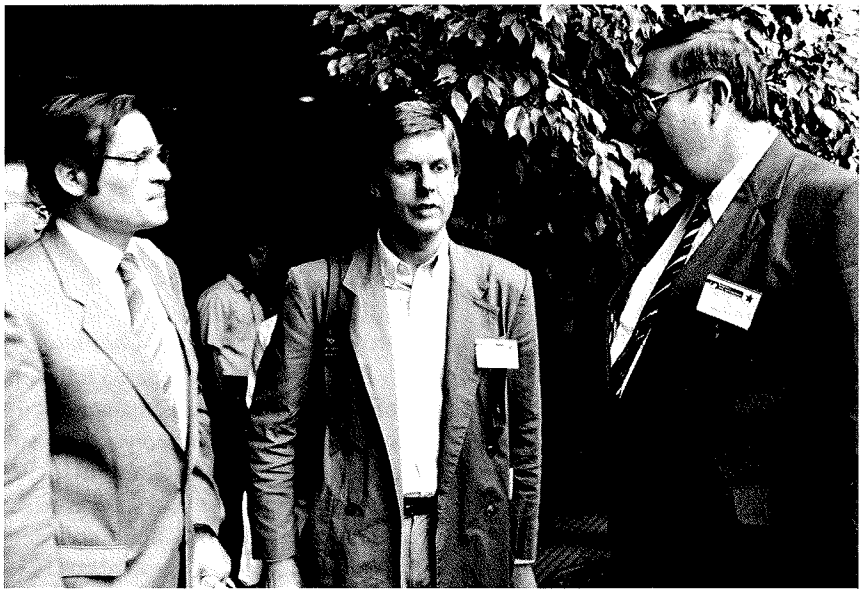
On Tuesday morning plenary speaker **Dr. K. Kurokawa,** Director of Research for Fujitsu Corporation, Japan, spoke on managerial strategies to maintain communication between the research, development, manufacturing, and marketing components of industry and the importance of instilling a respect for quality in employees.

Dr. Kurokawa, clearly addressed his remarks to the Americans, although he expressed concern that Japan, after struggling heroically to rise up from the devastation of the war, may be in danger of relaxing its own standards for quality.

The audience listened intently as Dr. Kurokawa, one of the most influential individuals in Japan's industrial establishment spoke to them in clear and careful English, spiked with flashes of wry humor..

Other plenary speakers were **Dr. J. Alic** of the U.S. Office of Technology Assessment and **Dr. John White** of the National Science Foundation.

Dr. J. Alic gave his views on **U.S. Manufacturing: An Agenda for Competitiveness.** On Thursday, Dr. John White presented **An Automation Report Card** for U.S. R&D programs and industry.



General Chairman Dr. Richard Volz (R) welcomes Chris Kozlowski of the Technical University of Polmo, Poland and Harold Rieseler from the Technical University of Braunschweig, W. Germany to Cincinnati. *(Thanks to Hendra Soetjahja of Columbia University for the photograph)*

Undersea exploration, one of the most exciting current applications for robotics, was addressed at the conference banquet when **Dr. D. Yoerger** of the Woods Hole Oceanographic Institution spoke on **Exploring Shipwrecks in the Deep Ocean with Telerobotics.**

Technical Program Chairman **A.J. Koivo,** his committee, and all the reviewers should be commended for the selection of papers and the organization of the technical sessions.

The technical papers presented at the 72 different sessions focused both on the heavy mathematics and physics which are the basis of the design of everything from video games to robotic welders and present and future applications of the new technology.

The non-stop conversations taking place in the hotel corridors, Cincinnati bars, aboard Ohio River cruise ships, and even the bleachers at the Reds games covered broader issues also.

Since more than a third of the conference participants represented foreign research institutes, including some from eastern Europe and mainland China, international politics and economic and environmental concerns were topics of lively concern, in particular the impact of developments in Germany and eastern Europe on the international research community.

R&A Society Technical Committees

Prof. T. J. Tarn,
Washington University
Vice President for Technical Activities

The Robotics and Automation Society now has nine technical committees.

The purpose of the Technical Committees is to promote the exchange of scientific information in specific fields of interest.

The possible activities for the technical committees are unlimited and can include workshops or special sessions at our annual Robotics and Automation Conference. If you are interested in joining the activities of any of the following technical committees, please contact the committee's chairperson listed below.

Computer-Aided Production Management
Prof. Peter Luh, Dept. of Electrical & Systems Engineering, University of Connecticut, Box U-157, Storrs, CT 06268, Phone: (203)486-4821

Future Directions
Prof. M. Vidyasagar, Center for Artificial Intelligence & Robotics, Raj Bhavan Circle, High Grounds, Bangalore 560 001 INDIA.
Phone: +91 812 27803 (0)
+91 812 540175 (H)
FAX + 91 812 75615
and
Prof. John Baillieul
Aerospace & Mechanical Engineering, Boston University, College of Engineering, 110 Cummington Street, Boston, MA 02215
Phone(617)353-9848

Intelligent Instrumentation & Measurement Systems
Prof. Janos Sztipanovits, Dept. of Electrical Engineering, PO Box 1824, Sta. B, Vanderbilt University, Nashville TN 37235
Phone (615)352-3455
FAX (615) 343-6702
e-mail : szstipaj@vuse.vanderbilt.edu

Robotics Motion Planning
Prof. Vladimar J. Lumelsky, Dept. of Electrical Engineering, Yale University, New Haven CT 06520
Phone: (203)432-4249

Robotics Dynamics & Control
Dr. Oussama Khatib, Artificial Intelligence Lab, Computer Science Dept., Stanford University, Stanford CA 94305
Phone : (415)723-9753,
e-mail: khatib@cs.stanford.edu

Computer Vision
Dr. Roger Tsai , IBM T.J. Watson Research Center, Room 5-151, Yorktown Heights NY 10598
Ph. (804) 978-1437
e-mail rtsai@ibm.com.

Manufacturing Automation
Dr. Walter Trybula, Electronics Manufacturing Applications Center, General Electric Company, PO Box 8106, Charlottesville VA 22906
Phone (804) 978-6456
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Prof. Toshio Fukuda, Dept. of Mechanical Engineering, Nagoya University, Furo-cho, Chikusa-ku Nagoya 464-01, Japan,
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France

Newsletter Deadline
Copy for the Fall issue should be submitted by August 15. wes@ecelet.ncsu.edu, or mleahy@blackbird.afit.af.mil

Robot Motion and Path Planning

Dr. Vladimir Lumelsky, Chairman

The Committee prepared a Special Issue of the *IEEE Transactions on Robotics and Automation* on "Sensor-Based Planning and Control in Robotics". R. Brooks and V. Lumelsky were Guest Editors. The issue, which was published in December 1989, had 9 papers.

(cont. on page 7)

Philadelphia IEEE Chapter Sponsors Robotics Seminar

Dr. Richard Klafter
Temple University

On Saturday April 28, the Philadelphia Section of the IEEE sponsored an all-day educational seminar entitled ***"ROBOTICS: THEORY AND APPLICATIONS."*** Held at the University of Pennsylvania, the seminar was attended by about 80 people from .around the Delaware Valley. The purpose of the seminar was to give insight into practical as well as theoretical aspects of the field.

Three of the four expert speakers on the program, Dr.'s **Wesley Snyder** (North Carolina State University), **Antal Bejczy** (JPL), and **Vladimir Lumelsky** (Yale). were current members of the Robotics and Automation Society's AdCom. The fourth speaker was **Dr. George Hazelrigg** from the NSF.

Dr. Snyder opened the seminar by giving a succinct and well-planned introduction to robotics in which he gave a brief history, classified robots by geometry, discussed the importance of sensors and how several of them functioned within a robotics system, mentioned issues related to control structure, and finally introduced some "hot" areas of current robotics research.

This latter was particularly appealing to the graduate students who were present in large numbers.

Dr. Bejczy followed with "sensors and sensor-based control" in which he concentrated on non-vision-based external sensors. He provided the participants with a good feeling as to why external sensors are often necessary to permit robots to successfully perform complex tasks. Next, he discussed the functionality of proximity sensors and their application and then went on to cover certain tactile devices. Finally, force and torque sensors were introduced. Throughout, Dr. Bejczy referenced everything to practical space applications so that individuals in the audience who were hearing this material for the first time could easily see how it was applied.

After lunch, Dr. Vladimir Lumelsky talked about "Robot Motion: Collision Avoidance in an Uncertain World." Although this material contains a good deal of rigorous background, Dr. Lumelsky chose to present the ideas behind how a robot (either a mobile robot or a single arm) attempts to move from point A to point B in the presence of unknown obstacles. The algorithm was relatively easy to follow and the applications were anything but contrived. It was interesting to see how a human might handle the problem of moving a point robot through a maze without being able to see the walls until one was struck. One of Dr. Lumelsky's colleagues at Yale successfully negotiated the maze after quite a long time. The time and the path generated by a computer utilizing

("Philadelphia" cont. on page 9)

Reports From Technical Committees

(Cont. from page 6)

A second highlight of this Technical Committee's activities in 1989 was preparation of the IEEE International Workshop on Intelligent Robots and Systems (IROS'89). T. Arai of the University of Tokyo and V. Lumelsky of Yale University were program chairmen.

Intelligent Instruments & Measuring Systems (IIMS)

Janos Sztipanovits, chairman.

The first event sponsored by the IIMS TC was the Intelligent Sensory Processing workshop organized in the 1990 Robotics and Automation Conference. The common theme of the workshop was the theory and technology of model-based methodologies in processing and interpretation of sensory input signals.

The general field of interest of the IIMS TC is the collection and interpretation of sensory data in robotics and automation systems. Specific topics of interest include intelligent sensors, sensor fusion, use of machine intelligence for sensory data interpretation, intelligent monitoring and diagnostics, hardware and software architectures for intelligent instruments and measurement systems in robotics and automation.

Individuals interested in participating in the activities of the IIMS TC are invited to send their name, employer, address, and e-mail address to Dr. Sztipanovits.

Robot Applications in Nuclear Power Plants

Harry T. Roman
Public Service Electric and Gas Company

Over the last ten years since the Three Mile Island accident, many utilities have become active in the evaluation, testing, and demonstration of robotic devices. These devices have been used primarily in nuclear power plants, but have also found application in fossil power plants and in tasks involving the transmission and distribution of electrical energy.

Today's teleoperated robots can go into controlled radiation areas and perform routine surveillance and inspection tasks, thus reducing man-rem exposure and manpower costs.

Some can even perform minor tasks such as material retrieval, swipe sampling, and remote camera inspection.

For all practical purposes, these devices are mobile instrumentation packages designed to gather environmental and radiation data. Tomorrow's more sophisticated robotic devices will incorporate AI, improved sensors and on-board intelligence, and will be able to perform operation and maintenance tasks within power plants.

Already in nuclear power plants, whole families of applications are beginning to emerge for mobile robots. Spurred on by the need to reduce radiation exposure dose to personnel and to offset rising operation and maintenance costs, electric utility engineers have worked with robot manufacturers to develop the following application families.

- Inspection, Surveillance, Monitoring in Controlled Radiation Areas.
- Underwater Inspection
- Pool, Tank, and Pit Cleaning
- Surface Decontamination
- Internal Pipe Inspection
- Radwaste Handling
- In Containment Inspection
- Internal Equipment Inspection

In the future, robotic devices will be used in more extensive application families like:

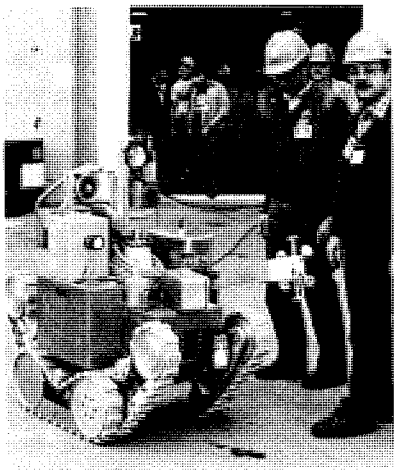
- Plant Security
- Spill/hazard Control
- Heavy Equipment/Tool Transport
- Decommissioning

But, there are practical limits to the use of robots in existing power plants. Too many site specific problems tend to limit the economic application of mobile robotic devices and/or compromise the full range of their capabilities.

To be truly effective, mobile robotic devices should be integrated into the design and construction of new power plants. A confluence of robotic technology from the space program and the construction industry will make this possible in the early part of the next century.

Public Service Electric and Gas Company (PSE&G) is a recognized pioneer in the application of robotic devices in the utility industry. Since 1987, the Company has installed approximately $1,000,000 of robotic hardware at its Salem and Hope Creek nuclear power plants, with total savings to date in excess of $1,800,000.

The **MiniRover underwater inspection vehicle** with camera system and radiation measuring instrumentation, has been used to inspect the reactor pressure vessel of the Salem 1 unit, and the fuel transfer channel of Salem 2. These applications have saved a total of $648,000. The MiniRover system cost $54,000. **SURBOT-T** (below) is another robotic vehicle now on duty at Hope Creek to perform routine inspection, monitoring, and surveillance tasks in controlled radiation areas within the plant. Essentially a rolling instrumentation package, SURBOT-T can monitor the environment in a controlled area and send back valuable information to the robot's operator. SURBOT-T can even take a swipe sample of a surface to be analyzed later to determine levels of contamination present.. When fully operational with experienced operators, SURBOT-T is capable of saving $200,000 per year. In the future, SURBOT-T may be fitted with a pair

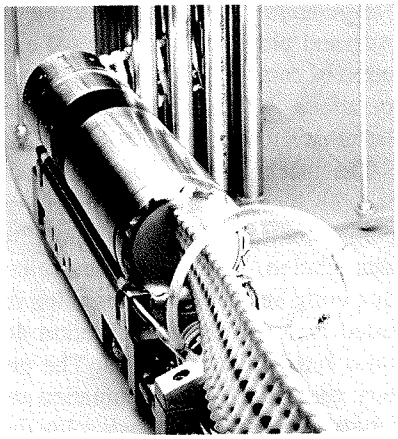


The SURBOT-T remote inspection vehicle on site at Hope Creek.

of arms to perform simple maintenance tasks.

One of the most critical pieces of equipment in a nuclear plant is the steam generator. It is vitally important to monitor the internal conditions of this major plant component and to remove any sludge and deposits that may accumulate.

The **CECIL** robot (below) originally developed by ConEd, EPRI, Foster Miller and the Empire State Electric Energy Research Corporation, and further supported by additional research by PSE&G, was used at Salem.



Cecil robot used to inspect steam generator at Salem #1.

An operator moved CECIL through the main galleyways of the steam generators and caused the robot to project a lancelike inspection ribbon down the long rows of tubes. A camera at the end of the ribbon allowed the operator to see deep inside the tube bundles for accumulated sludge and/or debris.

A high pressure water spray capability is built into CECIL's lance to allow the operator to flush sludge and debris away from the tubes within the steam generator. PSE&G is sponsoring modifications which will provide the ribbon with miniature tools that can be used to remove entrapped deposits which cannot be flushed away with high-pressure water.

PSE&G's other robots have been used to perform underwater floor cleaning of spent fuel pools, reactor cavity decontamination, pipe inspection, general floor area decontamination, and inspection of the under vessel torus at Hope Creek.

The Company is now evaluating robotic devices for its fossil power plants, and developing robotic devices to inspect and test electric meters. In 1990, PSE&G will establish the Applied Robotics Test (ART) Facility to serve as a laboratory to test and demonstrate new robotic applications as well as train PSE&G's future robot technicians and operators.

Harry T. Roman, Principal Engineer for Research at PSE&G is president of the Utility/Manufacturers Robot Users Group (U/M RUG). This nationwide group was formed to foster the cost effective application of robotic devices within the electric utility industry. Today, 157 organizations, including international representatives, belong to U/M RUG, with 204 people receiving minutes from its three meetings per year. Thirty-seven of the member organizations are utilities.

(Philadelphia Seminar, Continued from Page 7)

his algorithm was then shown. Finally, a discussion of how this technique was applied to a real robotic manipulator was presented along with a description of the special sensitive "skin" that was designed. An impressive video tape of the arm being asked to avoid various stationary and moving obstacles was shown.

The last speaker was Dr. George Hazelrigg from the National Science Foundation whose presentation was entitled "Microrobotics: Investigation in Microelectromechanical Systems."

Dr. Hazelrigg discussed the potential of this new field to revolutionize many existing industries as well as acting as the catalyst for creating many new ones. Two applications or potential applications are: 1) microminiature sensors for industry and medicine and 2) medical devices that can be placed into the blood stream of a human. In the latter case, mechanical problems such as bad heart valves or clogged arteries could be repaired without the need for invasive surgery (the Fantastic Voyage come true!). Because sensors will eventually be very inexpensive, it will be possible to fully close the control loop of many electromechanical systems such as robots, aircraft, or automobiles. Control will be much more precise for such systems. Moreover, these sensors will permit monitoring for safety purposes so that metal fatigue and/or corrosion could be detected early on. Dr. Hazelrigg said that this year, it is expected that the ability to produce, on a chip, functional small actuators, gears, and mechanical assemblies will produce gross sales (mainly sensors) around $2 billion. Predictions are for the area to grow in 20 years to $100-200 billion per year.

At the conclusion of the seminar, typical participant's comments were "...this was one of the most worthwhile professional events that I've ever attended." and "...each speaker was better than the last one and they were all great!" Thanks are due not only to the speakers but also to the organizers: Ruzena Bajcsy (University of Pennsylvania), Allon Guez (Drexel University), Richard Klafter (Temple University), Anthony Palmieri (GE), Edward Shamsi (GE), Harry Urkowitz (GE), and Harris Zebrowitz (Flam & Russel).

Robotics Research at JPL

C. Weisbin and D. Perrilard
Jet Propulsion Laboratory,
California Institute of Technology

The Jet Propulsion Laboratory (JPL) of the California Institute of Technology (Caltech) is a federally funded research and development center that operates under contract to the National Aeronautics and Space Administration (NASA). The staff of JPL share a common objective: research and development in the national interest with emphasis on exploration of the solar system. With Voyager 2's encounter of Neptune in August 1989, JPL spacecraft have explored every known planet with the exception of distant Pluto.

JPL's main campus is located in the foothills of the San Gabriel Mountains and three other sites in Southern California-- at Edwards Air Force Base, Goldstone, and Table Mountain. In addition, JPL manages deep-space tracking facilities in Spain and Australia. Of the more than 6300 people employed at JPL, over 4000 hold degrees in engineering and science.

Three institutional characteristics shape JPL's philosophy, mission and goals: (1) as part of Caltech, JPL seeks the highest standards of scientific and engineering achievement, with excellence, objectivity, and integrity as guiding principles; (2) as NASA's lead center for unmanned exploration of the solar system, JPL has led the United States in lunar and planetary missions since the space age began; and (3) as a federally funded research and development center, JPL helps conduct work for other federal agencies to help solve technological problems of a long-term, high-risk nature.

Automation and Robotics at JPL

Automation and robotics technology has been critical to the success of a long series of JPL missions for planetary observation and exploration. Planetary exploration by unmanned spacecraft has led the way in the development and implementation of intelligent automation, the ability to accomplish assigned objectives or goals by automatically devising an efficient course of action, utilizing available resources on the basis of the perceived environment, and reporting externally the status of accomplishment and system capabilities. This development has been driven by the special requirements of planetary exploration: communication delay, telemetry bandwidth restrictions, interruptions of the communication link, inaccessibility by humans, and complexity and time criticality of the science acquisition sequences.

Automation and robotics technology development enables enhanced system performance at reduced cost by (1) optimizing the allocation of intelligence to the remote and local sites; (2) providing methodology for modular and hierarchical design of remote autonomous systems which can be readily standardized; (3) enabling remote mobile operations, such as planetary surface exploration, which would not otherwise be feasible by today's manned exploration technology; (4) identifying and developing technology with long lead-time for flight applications.

Target Applications

The primary target applications for space automation and robotics technology are: (1) low-cost robotic planetary spacecraft for solar system exploration including survey, preparation and operation on lunar and planetary surfaces: (2) dexterous and mobile manipulators to assists operation on lunar and planetary surfaces; (3) execution of complex servicing and repair operations on earth-orbiting space platforms and systems.

The technology base in man-machine interface, planning and reasoning, control, perception, mobility, manipulation, system architectures, computing and systems integration required for these three application domains has similar elements. The primary goals of the JPL Automation and Robotics activities are: to develop this technology base; to conduct system applications studies aimed at identifying problem areas in which automation and robotics technology can contribute; and to transfer items of technology to planetary and earth-orbiting flight projects as appropriate.

Laboratory Facilities

JPL Automation and Robotics activities utilize six major mutually complementary laboratories.

Telerobotic Testbed: Ground-Controlled Remote Manipulation This laboratory investigates solutions to the problem of how to best combine the efforts of man and remote intelligent machine(s) in the remote execution of complex space tasks. Emphasis is on evolution from teleoperation to remote system automation supervisory control and the fluid transi-

tion between teleoperation and autonomy.

- **Redundant Dual Arm Control Laboratory** This laboratory aims at research and development in the areas of advanced modeling, adaptive control, hierarchical control software architectures, complex system task simulation and analysis, motion and force planning, and symbolic/numeric concurrent computation, as they pertain to redundant dual arm manipulation systems.
- **Autonomous Mobile Vehicle Laboratory** This laboratory provides a testbed for investigation of: real-time planning in uncertain terrains; wheeled locomotion and mobility, image processing for Rover control, and combined mobility and manipulation.
- **Robotic Sensing and Perception Laboratory** This laboratory explores innovative multi-resolution pyramid approaches to machine vision and computation including automatic acquisition, tracking, and grappling of 3-D labeled and unlabeled objects in arbitrary and unknown motion. It also explores issues in machine perception and multi-sensor fusion for robot control.
- **Advanced Teleoperation and Man-Machine Systems Laboratory** This laboratory investigates man-machine interface issues in advanced teleoperation and supervisory automation, including development of electro-mechanical and computing architectures supporting experimentation. The goal is to quantify human factors requirements and optimize technology designs with respect to perception, motor skills, ergonomics, and decision support.
- **Robotic AI Planning and Reasoning Laboratory** This laboratory explores the application of AI techniques to the problems of task planning, motion planning and geometric reasoning, and execution monitoring and diagnosis for anomaly recovery.

For a more detailed description of these facilities and the research performed in them, contact Dr. Charles Weisbin, Manager, Robotics and Automation Section, JPL, 4800 Oak Grove Dr., Pasadena CA, 91109-8099. (818)354-2013, Fax (818)393-5007 Weisbin@robotics.jpl.nasa

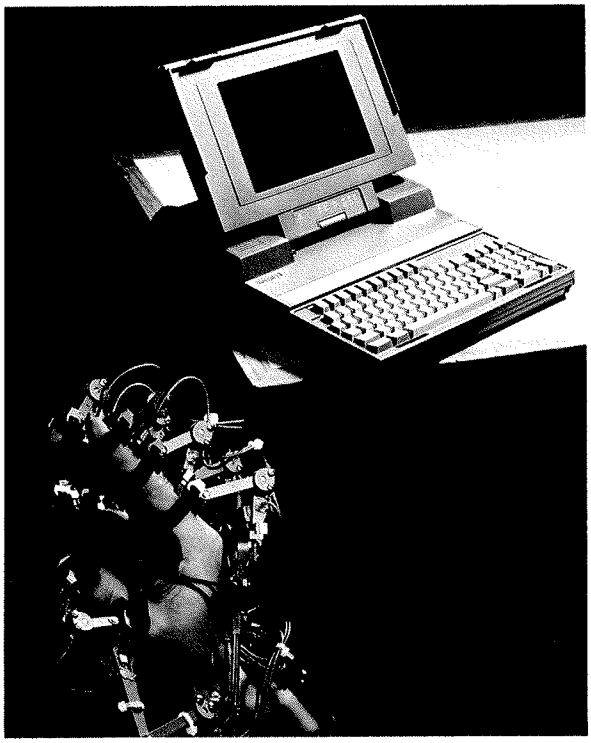
New Products

Exos, Inc. of Burlington MA has released a new version of its robotic hand controller, the Dexterous Hand Master (DHM). The Series 2 DHM offers a simple, easy-to-use method for understanding and controlling robotic hands. In addition it provides accurate and repeatable measurements of human hand motions. Customer applications include musical performances virtual environments and human factors engineering.

The sensor technology was originally developed at Arthur D. Little as an outgrowth of research carried on for NASA..

The DHM, an exoskeleton which is worn on the hand, senses three bending motions plus the side-to-side motion of each finger. A total of 20 joint angle measurements are sent to specially designed electronics, which plug into a computer. The data is displayed and recorded for later analysis.

For more information contact: Wendy Lucas, 8 Blanchard Rd., Burlington MA 01803, Tel. (617)229-2705



telescope of Nobeyama Observatory of Tokyo University, and a new interstellar molecule was discovered. Two more years later, a new market for HEMT was opened up unexpectedly. Satellite broadcasting began and the demand for low noise microwave amplifiers skyrocketed to reduce the size of receiving dish antennas. The mass production of HEMT discrete devices began. HEMT was accepted by the marketplace.

We are now pretty sure that HEMT has at least one strong point: low noise at microwave frequencies, and hence high-speed operation. We still have two or three more years to go before HEMT is used in real computers.

However, our engineers are all in high spirits, and our top executive officers no longer express doubts. Although I know the HEMT project still needs careful management, I can now express cautious optimism, thanks to our application of the concept of graceful growth. The early entrance of HEMT into the marketplace helped to reduce an anxiety from which otherwise everybody involved might have struggled.

Effective Manpower

Now, I would like to discuss the effective manpower for achieving a breakthrough, such as an invention or a discovery. HEMT was invented by one person, Mimura, and the first working model was constructed by just two persons. Hiyamizu grew the crystal and Mimura performed all the necessary processing and tests.

How many cooks are too many?

An invention is rarely made by a committee. It is usually made by a small number of dedicated people. Why? Because too many cooks spoil the broth. Now the question is, how many cooks are too many?

In an exploratory study, many ideas seemingly trivial or ridiculous have to be tried out in succession. The outcome is uncertain although it be comes obvious by hindsight.

In this kind of situation, the very possibility of being laughed at or criticized prevents ideas in their embryonic stage from coming out in consciousness. Thus the involvement of a large number of people becomes harmful rather than helpful.

To explain how many cooks are really too many, let n be the number of people involved and q be the probability of two persons cooperating wholeheartedly without criticizing the apparent triviality or absurdity of any idea.

If a pair of persons among n cannot cooperate wholeheartedly, then ideas in their embryonic stage are killed. The number of pairs among n is given by $n(n-1)/2$.

So the expected value of manpower effectively used in the formation of a new idea, or the effective manpower in short, is given by n times q to the $n(n-1)/2$ power.

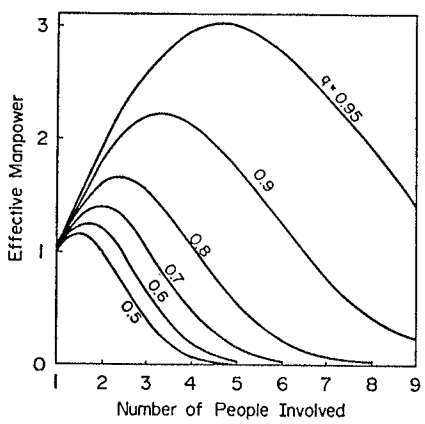


Fig. 4 Effective manpower vs. the number of people involved

Figure 4 shows the effective manpower vs. the number of people involved. If q is 80%, no more than 2 persons should be involved. If q is 90%, no more than 3 persons should be involved.

One may well realize how difficult it is for two persons to cooperate wholeheartedly 90% of the time. Then, the maximum numbers of people for an important invention may be 3. Managers must be careful not to intervene in the process of achieving a breakthrough by trying to give helping hands.

Probability of Success

Finally, I would like to discuss the probability of success in technology transfer. From my own experiences in R&D , I have realized that successful technology transfer does not take place unless all the people involved think in the same way simultaneously.

Suppose the probability of one person concurring with his subordinate is p and the probability of one person and his counterpart in another group have the right chemistry is q.

Then the probability of a successful transfer is given by

$$p^{m-1+n}q^{n}$$

where m is the number of ranks in the hierarchy of the transferring group and n is the number of ranks in the hierarchy of the receiving group, as illustrated in Figure 5.

Suppose p is a very reasonable 80% and q is 60% and m=7 and n=4. Then the probability of success is 1.4%, a frightening number. If one more transfer is required, then a factor of $p^n q^n$ has to be multiplied and the result becomes 0.074% .

This explains very well why a large institution is almost always a poor innovator. The role of managers is, then, to increase p and q and effectively decrease m.

A method used to decrease effective m is ***management by walking***

If a pair of persons cannot cooperate wholeheartedly, then ideas in their embryonic stage are killed

around. Managers walk around the labs and chat with researchers at their own workbenches. This creates casual but valuable interaction between managers and researchers. Sony's Walkman and HP's calculators are two well-known results of this doctrine.

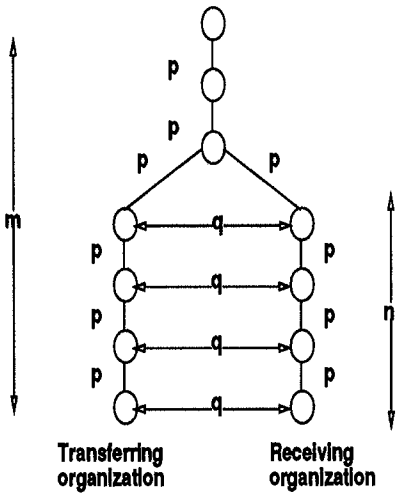


Figure 5 The effect of hierarchy on technology transfer

Stick to the knitting is an effective way to increase p and q. Examples of not sticking to the knitting are abundant: for example, Exxon's attempt into Electronics, TI's digital watch, and GE's coal mining. As you know they all gave up their attempts. Fujitsu did not stick to the knitting when Okada was president. However Okada learned to communicate with engineers, reducing effective m. And that is why Fujitsu is a computer company today.

Conclusion

In summary, I have presented the stories of three leaders in the Japanese electronics industry. Then I discussed five topics: quality, excessive division of labor, graceful growth, effective manpower for a breakthrough, and the probability of success in technology. I hope the stories of these three gentlemen gave some insight into the differences and similarities in the two countries and the five topics clarified the following: Quality, innovation and breakthrough each require entirely different approaches in management.

Call for Videos

The 1991 IEEE International Conference on Robotics and Automation plans to issue video proceedings. Videos are hereby solicited in all aspects of experimental work and demonstrations in robotics and automation. Accepted videos will be edited and released through IEEE on VHS tapes. Authors interested in submitting videos for review should meet the following criteria:

1. Video presentations are limited to 3 minutes. An audio presentation should accompany the video recording.
2. A write-up up to two pages describing the videotape should be submitted along with it.
3. We will accept videos that are either intended to be used at the 1991 Robotics and Automation Conference presentations or present experimental not connected with the conference papers. All accepted tapes will be shown in a **Video Session.**
4. We recommend that the tapes be recorded on 3/4" U-matic video or at least a super grade high fidelity super VHS tape. For better quality, one may wish to use any one of the following recording formats: 16mm film, 35mm film, Betacam, or 1" type c video.

Submissions: One copy should be sent by **October 15 1990**
Prof. T.J. Tarn, Program Committee Chairman
Campus Box 1040
Washington University,
St. Louis MO 63130
FAX: (314)726-4434, Tel: (314) 889-6037
e-mail:tarn@wurobot.wustl.edu
Authors will be notified of acceptance by **January 15, 1991.**

Calendar

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 Univ. 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. A.A. 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.

September 5-7 5th IEEE Symposium on Intelligent Control. Philadelphia PA. *Sponsor:* IEEE Control Systems Society.

September 1-10, International Summer School & Workshop on Neurocomputing. Dubrovnik, Yugoslavia. *Sponsor UN European Centre for Peace & Development..* Kneza Mihaila 7/II, 11000 Belgrade Yugoslavia. Tel 38 11 633 551. FAX 38 11 62..

September 18-21 Int. Conference on Automation, Robotics, and Computer Vision. Singapore. *Sponsor:* Nanyang Technological Institute.

September 27-28. Robot Olympics. Glasgow Scotland. *Sponsor* The Turing Institute. SEE CALLS FOR PAPERS.

November 26-29 IEEE Conference on Neural Information Processing Systems - Natural & Synthetic Denver, Colorado. NIPS-90 Post-Conference Workshops will be Nov. 30-Dec.1 at a ski resort near Denver. *Contact:* Kathie Hibbard NIPS*90 Local Committee, Engineering Center, Univ. of Colorado, Campus Box 425, Boulder CO 80309-0425.

January 30-February 2 1991. 4th IEEE Workshop on Micro Electro Mechanical Systems (MEMS). NARA Japan *Sponsor:* IEEE Robotics & Automation Society in coop. w/ IEE of Japan and the ASME Dynamic Systems & Control Divisions. SEE CALLS FOR PAPERS.

April 7-12, 1991. IEEE International Conference on Robotics & Automation. Sacremento CA. *Sponsor:* IEEE Robotics & Automation Society. SEE ANNOUNCEMENT

June 20-22, 1991 5th International Conference on Advanced Robotics: Robotics in Unstructured Environments. Pisa Italy. *Sponsor:* CNR (Nat'l Research Council of Italy) and others. *SEE CALLS FOR PAPERS..*

Position Available

McGill University

The McGill Research Centre for Intelligent Machines has been constituted as an interdisciplinary grouping of researchers in Computer Science, Electrical Engineering, Mechanical Engineering and Biomedical Engineering. It consists of three groups: the Computer Vision and Robotics Laboratory, the Robotic Mechanical Systems Laboratory, and the Systems and Control Group. There are 17 professors and about 100 graduate students in the Centre. The Centre possesses outstanding facilities for research and provides an excellent academic milieu.

The Centre is seeking to fill two tenure-track positions at the Assistant Professor level specializing in Sensor-Based Robotics. One of these positions is in the Department of Electrical Engineering and the other in the Department of Mechanical Engineering. It is expected that the candidate will be integrated into one of the existing sub-groups in the Centre. The candidate should be a recent doctoral graduate with a strong interest in research and teaching. We are looking for outstanding candidates who see themselves as potential leaders in the field. Excellent communication and teaching skills are a must. An interest in industrial collaborative projects is required.

In accordance with Canadian Immigration requirements, this position is offered in the first instance to Canadian citizens and permanent residents.

Interested people should send their Curriculum Vitae and the names of three references to: ***Professor Martin D. Levine, Director, McGill Research Centre for Intelligent Machines, McConnell Engineering Building, 3480 University Street, Montreal, Quebec, H3A 2A7.***

Calls for Papers

1st International Robot Olympics. September 27-28, 1990. *Sponsor: The Turing Institute, Glasgow Scotland.*

Although there will be categories for teleoperated or semi-autonomous machines, it is hoped to attract robots which exhibit autonomous behavior; i.e. robots which demonstrate an intelligent connection between perception and action. Within this broad category, overall group winners will be on a scoring system taking into account the quality of the engineering and design, the sophistication of the demonstrated behavior and the novelty of the device. Importantly, any robots claiming similar capabilities will be pitted against each other in competition. It is expected to be able to hold events such as hexapod races, biped races, obstacle avoidance competitions and speech communication skill tests. Aquatic variants are also welcome

For information contact: Michelle Johnstone, Robot Olympics Secretary, The Turing Institute, George House, 36 N. Hanover St., Glasgow G1 2AD UK. FAX 41 552 2985 TEL 41 552 6400.

When making inquiries please specify whether you are a (1)Competitor (2)Press and media (3)Sponsor(4)Exhibitor (5)General.

4th IEEE Conference on Micro Electro Mechanical Systems (MEMS). Jan. 30-Feb. 2., 1991. *Sponsor:* IEEE Robotics & Automation Society *in cooperation with* IEE of Japan and the ASME Dynamic Systems & Control Divisions.

The Workshop embraces the design, fabrication, operation and application of devices, machines and systems constructed of millimeter-scale or smaller electromechanical elements.

Prospective authors should submit a one-page abstract with an additional page for figures by **September 16, 1990.** Recent MEMS developments can be submitted as two-page abstracts for consideration as Late-News papers by **November 15, 1990.**

Send all correspondence to:
IEEE MEMS-91 Workshop
c/o MESAGO Japan Corp.
Palais Eternel 1004 28-30 Yotsuya 4-chome
Shinjuku-ku Tokyo 160 Japan
Tel: 81 3 359 0894
FAX 81 3 359 932

Fifth International Conference on Advanced Robotics: Robot Systems in Unstructured Environments. June 20-22 1991, Pisa ITALY.

Sponsors: CNR(Nat'l Research Council of Italy, Consorzio Pisa Ricerche, Scuola Superiore "S. Anna, Pisa, University of Genoa, University of Pisa, In cooperation with IEEE Robotics & Automation Society, INRIA, (France) , Japan Industrial Robot Association, Italian Association for Robotics. ***ICAR*** was established in 1983 to be the primary event for illustrating national and international projects on advanced robotics.

Submissions: 4 copies of full papers (8-10 double-spaced pages) in English should be sent to :
Prof. Paolo Dario
'91 ICAR Secretariat
Consorzio Pisa Ricerche
Via Risorgimento 9 I-56126, Pisa Italy
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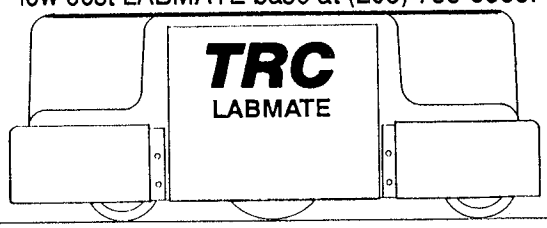

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