Newsletter of the IEEE Council on

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ROBOTICS AND AUTOMATION

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As I mentioned in the President's message in the last issue of the Newsletter, the Robotics and Automation Council will become a Society in 1989. The first order of business of the Council/Society is the election of an Administrative Committee which shall consist of 18 members rotating on three-year terms. This Adcom functions like the Board of Directors of a corporation and elects the President in addition to being the operating arm of the Society. An advisory committee consisting of the four past Presidents of the Council is working with the President-elect, Prof. Art Sanderson, me, and the chairman of the nominating committee, Dr. Antal Bejczy, to come up with a slate of candidates for Adcom membership.

However, as I mentioned in my last letter, anyone can be nominated with the signatures of 25 members (i.e., current subscribers to the IEEE R&A Journal). The nominating committee also wishes to consult widely to insure proper representation of all segments of the society. To this end, I urge anyone who is interested in the affairs of the society to volunteer him/herself. Just send to me or to Dr. Bejczy at JPL.

1. A short bio and resume
2. Areas of your expertise
3. Interests in volunteering in areas such as review of papers, conference organizations, etc.
4. Name/s of at least one person we can contact for a reference.

While we may not be able to nominate everyone who volunteers to the governing board, the Society has many other appointed positions of importance that may be able to use your service. Furthermore; each year the new President must make a large number of appointments. It is important that he have an adequate pool of qualified volunteers to draw upon. Please do suggest yourself and others.

1989 IEEE INTERNATIONAL CONFERENCE ON

ROBOTICS AND AUTOMATION

May 14-19, 1989
The Registry Resort
Scottsdale, Arizona

Sponsored by the IEEE Council on Robotics and Automation

General Chairman: **George A. Bekey,** University of So. California
Program Chairman: **John Hollerbach,** Massachusetts Inst. of Technology
Treasurer and Coordinator: **Harry Hayman**
Local Arrangements: **A.L. Pai, Arizona State University**

ADVANCE ANNOUNCEMENT
and
CALL FOR PAPERS

The theme of this conference is intelligent robot systems, but original basic and applied papers in all areas of robotics and automation are solicited. Special topics related to the theme include, but are not limited to, the following:

- Artificial intelligence as applied to robotics
- Dexterous grasping, haptics, and tactile sensing
- Experimentally verified robot control
- Hand-eye coordination
- Intelligent robotics in manufacturing
- Legged locomotion
- Mechanical design of actuators and manipulators
- Micro-robotics and micro-actuators
- Mobile robots and navigation
- Novel non-visual sensors
- Qualitative physics and reasoning
- Sensors integrated into devices and control
- Task planning
- Telerobotics: man-machine interfaces, advanced devices, artificial environments
- Unstructured environments: space, nuclear, undersea, etc.
- Vision: real-world scenes, recognition, representation

The organizers encourage submission of non-commercial papers from representatives of industry, universities, research institutions, and government.

PAPER SUBMISSION: Four copies of papers should be sent by October 1, 1988 to:
John M. Hollerbach, MIT Artificial Intelligence Lab
545 Technology Square, Cambridge, Mass. 02139

Reviews will be conducted by a program committee of established robotics researchers. Invited sessions will be entertained, but their papers will be reviewed in the normal process.

Authors will be notified of acceptance and furnished with an author's kit by December 15, 1988. Final papers in camera-ready form will be due February 1, 1989. Final papers received by the deadline will be included in the proceedings available at the conference.

The conference hosts tutorials on Monday, May 15, 1989 and a workshop and tours on Friday, May 19, 1989. Conference sessions will be held on Tuesday, May 16 to Thursday, May 18, 1989. Prior to August 1, 1988, those with proposals for tutorials or the workshop should contact: **Alan Desrochers**
ECSE Department
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

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From the Editor

Wesley E. Snyder
North Carolina State University

In this issue, we have the conclusion of Prof. Marvin DeVries's paper on the need for integration of automation technology into the manufacturing process and the education of managers in the implications and potential of the new technologies, as well as reports on ongoing work in West Germany and Australia.

We often hear that "In order for American industry to be competitive with ... (usually Japan), we need to..." Those "we need to" comments are in fact applicable as well to those other countries in order for *them* to compete in the world marketplace. Another often heard phrase along these lines is the need for "University/industry/government cooperation", something which Japan and Germany are reputed to have solved particularly well.

I work for an Industry/University cooperative research center in North Carolina, and have just returned from six months with a government laboratory in Germany, and thus feel obliged to comment on this. Industrial sponsorship of American university projects is often accused of driving those projects toward short term goals. Yet in the article on Automation R&D in Germany, we learn that while research laboratories in that country receive a significant amount of their support from industries, they do excellent theoretical research In fact, in than respect Germany is *no different* from the United States: industry wants demonstrable results We do not see a lack of theoretical research there, but we do see a much larger **percentage** of effort within a given center being devoted to technology transfer. Concepts which are developed as theory papers are carried beyond the simulation stage, even beyond the breadboard stage, to a manufacturable prototype, *within the same laboratory in which they were originally derived.*

Such a model is quite different from the American university model. We tend to consider a research project complete when simulations show feasibility. "Somebody else can do the development" we say. Yet that development is most efficiently done in close proximity of the original developers of the idea.

Several models have been proposed and used to provide that interaction: company engineers working at the university (assuming the theoretical work was done at a university), sabbatical leaves for faculty to work at industry for a year, summer appointments for students and faculty, etc., and all of these models work to some extent. However, my observation from Germany was that *the most effective mechanism for technology transfer is the location of full-time, permanent engineers at the site where the theoretical work is done, whose job it is to carry the theory to a manufacturable prototype.*

This has significant economic impact on university research systems. Development to the prototype stage is typically many times as costly as the original theoretical concept; ownership of patent rights opens up a massive bag of legal worms; and so forth. But these problems can and have been solved. Most research universities already have some structure in place for accomplishing this goal such as industrial extension services, which can provide the engineering manpower to manage development projects and deal with industrial clients.

By making a commitment to development in addition to theoretical research, universities and government laboratories make themselves much more attractive to industry, because industry sees real, usable outputs. Industry, however, must be aware of the cost. No longer is sponsorship of a university project simply paying for one graduate student and 10% of a professor for one year. The cost goes up radically, yet it is a cost that industry must be willing to pay to see genuine technology transfer.

IEEE Fellows Nominations

Among the rights and responsibilities that the Robotics & Automation Council will assume when it becomes an IEEE Society in January 1989 is active participation in the nomination and evaluation of candidates for the grade of IEEE Fellow. Prof. George Saridis of Rensselaer Polytechnic Institute will be Chairman of the R&A Society Awards Committee.

Designation as an IEEE Fellow is conferred only by invitation of the IEEE Board of Directors upon a person of outstanding and extraordinary qualifications and experience in IEEE designated fields (including electrical engineering, electronics, computer engineering, and computer sciences, and the allied branches of engineering and related arts and sciences), who has made important individual contributions to one or more of these fields. The stringent nomination and review criteria include evaluations by the *one* IEEE society which best reflects the candidate's field of technical accomplishments, and opinions of confidential Fellow references who are qualified to judge the candidate's work.

The IEEE Board of Directors and the Fellow Committee are seeking to enhance the recognition accorded to the outstanding electrical engineering practitioners as well as that accorded distinguished academics and theoreticians. The work of the practitioner is product design

IEEE Fellows
Robotics & Automation

J.K. Aggarwal	Herbert Freeman	Martin D. Levine	W.R. Perkins	Tzyh-Jong Tarn
Suguru Arimoto	Jose Garcia-Santesmases	Peter A.Lewis	Bernard Picinbono	John A. Tegopoulos
A. Avizienis	Leonard B. Gardner	Ching C. Li	Kennard Pinder	F.T. Thompson
George S. Axelby	Elmer G. Gilbert	Lennart Ljung	Veljko Radeka	J.T. Tou
Tamer Basar	R.C. Gonzalez	John C. Lozier	Edward A.E. Rich	Spyridon G. Tzafestas
M.P. Bachynski	Graham C. Goodwin	J.Y. Luh	Peter L. Richman	P.M. Van der Grinten
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R.D. Cutkosky	Rangasami L. Kashyap	Yoshiei Nakano	R.A. Soderman	C.C.Cutler
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S. Duinker	P.R. Kumar	James D. Palmer	Ching Y. Suen	
P.Eykhoff	G.C.Lendaris	T. Pavlidis	Noboru Takagi	

and applications, and the construction, operation, and evolution into practical use or manufacturing of items or systems. It has been difficult to provide outstanding practitioners with proper recognition, partly because proprietary considerations of the corporation sometimes prevent full documentation of their contributions in the open literature. While the evaluation criteria for practitioners nominated as IEEE fellows will be as stringent if not more so than for those whose work is documented in the open literature, such nominations will be given special attention by the Society Evaluation committees and by the Fellow committee.

New IEEE Fellow nomination kits will be furnished upon request from the Staff Secretary, IEEE Fellow Committee, 345 East 47th Street, New York, NY 10017 (212/705/7750). A list of the R&A members of Fellow grade, who are eligible to provide references for nominees, is published in this issue to assist those who would like to participate in the nominating process.

Robot Safety Focus Group Formed

The first meeting of the Focus Group on Safety, Reliability, and Human Factors was held during the 1988 IEEE International Conference on Robotics and Automation with a small but enthusiastic turnout. Attendees at the meeting represented a good cross-section of robot users and researchers from academic, industrial and government institutions. The purpose of the meeting was to assess the level of interest in robot safety among IEEE members and to ascertain what types of activities could best benefit those interested members. The consensus of those present at the meeting was that the IEEE can best serve this area by encouraging and publishing research in this area. It was pointed out that robot safety application are regularly reported in the conferences of Robotics International of the Society of Manufacturing Engineers (*ROBOTS11*, *ROBOTS12*, etc.), and that the Robotics Industries Association has developed a standard for safety requirements for industrial robots, which is now available as ANSI/RIA R15.06 from the American National Standards Institute.

Since the ANSI/RIA standard deals mainly with industrial robots which are usually anchored by a fixed base and often enclosed by a protective barrier, it was felt that many current applications of robotics will not be well served by this standard. Cited in particular were mobile robots, use of robots in laboratory automation, and use of robots in human service applications.

Any member of the IEEE Robotics and Automation Society who would like to participate in future activities of this focus group are encouraged to contact either Prof. Antii Koivo at Purdue University (317-494-3436), Prof. James Graham at the University of Louisville (502-588-6304), or Dr. D.H. Raheja of Technology Management, Inc. (301-792-0710).

The Industrial Renaissance:
Trends and Educational Implications

Martin F. DeVries

Part 1 of Prof. DeVries's article, Technological Trends, was published in the Summer 1988 newsletter.

Part 2: Educational Implications

It is essential to examine how the industrial renaissance of which we speak specifically impacts us as professional engineers and managers and how our current educational process must be modified to provide the proper type of entrance level graduates. As we have noted, the most significant characteristic of the current renaissance is the recognition of the reintegration of the manufacturing activity. The early craftsman was totally responsible for all aspects of a product; he executed the design, procured the material, performed the transformation process, delivered the product, and provided service to the customer. The results of Taylor's teachings led to a division of labor, where manufacturing became a compartmentalization of highly specialized activities. Manufacturing was viewed as a series of unit processes through which material passed, utilizing a minimum of data and depending to a great extent on the knowledge base of skilled employees who understood the objectives of the operation, treated problems in empirical ways, and responded to management experience in the business, rather than in engineering and scientific knowledge. As a consequence, the engineering profession went from the complete engineer of a Leonardo da Vinci to the generation of individuals who are intensely specialized in our now traditional disciplines. The reintegration of manufacturing demands a change in the traditional education of individuals entering this field.

Traditional Approaches

Until recently, practically any mechanically inclined person could master the most complex aspects of manufacturing. Now only as small percentage of engineers can even comprehend the wide range of sophisticated processes, equipment, and methodologies of manufacturing. Future participants must possess knowledge and skills far beyond those previously required. Most degreed engineers currently working in manufacturing were educated in either mechanical or industrial engineering disciplines. The potential manufacturing engineer received an education concentrated in such areas as materials science, thermodynamics, solid and fluid mechanics, heat and mass transfer, and occasionally a course in the methodology of processing. As a consequence, engineering education for careers in modern manufacturing was not appropriate and few graduates entered this field. Industry increasingly met manpower needs for manufacturing engineers by promoting machine operators and manufacturing technicians from within the organizations.

In general, industry had not established clearly defined career development programs for manufacturing engineers within the organization. This group was not usually considered for staffing upper positions in the organization's hierarchy. Top management prospects from other engineering were given responsible positions in design, marketing, and finance along their upward career paths. Seldom was there need for this group to spend time on the shop floor, primarily because manufacturing technology was not considered to be an essential background for financial success of the organization. The lack of a strong demand from industry for engineers skilled in manufacturing was a significant signal to academia that it need not focus its limited resources on manufacturing programs.

The teaching of manufacturing to engineers at the university level was, until recently, a neglected area in the United States. Because of this situation, the schools which had manufacturing engineering curricula were unable to attract top students. As a consequence, there was a lack of an adequate supply of new academic personnel involved in manufacturing research and teaching. In addition, there was the failure to establish strong university-industry relationships in manufacturing areas at a time of rapid growth in the high-technology industries. Few universities developed relevant programs, resulting in only a few graduates being produced who were knowledgeable in any depth concerning basic manufacturing issues.

New Directions

Just as industry has recognized the inevitability of change brought about by the incredible pace of advancing technology, the academic world is beginning to respond to similar pressures to ensure that it not only stays abreast of change in its formal curricula, but is

at the forefront in the creation and development of basic manufacturing research that leads to innovations in the marketplace.

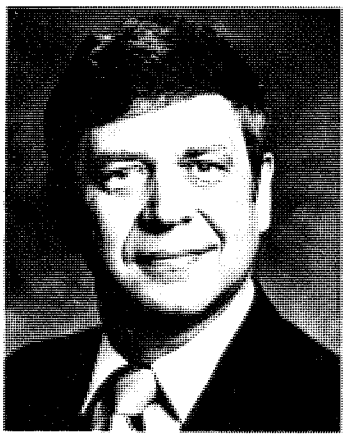
The decline in the appropriateness of manufacturing engineering education was increasingly recognized and a number of programs were formulated to reverse this trend. The Society of Manufacturing Engineers initiated its Manufacturing Engineering Education Foundation (MEEF) in 1979. MEEF has provided nearly three million dollars in grants to more than one hundred fifty educational institutions since its inception. The support has taken the form of capital equipment grants, student scholarships, faculty development funds, curriculum development grants, and manufacturing research initiation funds. MEEF support is provided to a broad spectrum of educational institutions with missions ranging from manufacturing technology to basic research. While the average amount of the grants is modest, they are often leveraged, resulting in significant positive impacts on the quality and quantity of manufacturing education.

In the fall of 1984, the National Academy of Engineering organized a symposium entitled "Education for the Manufacturing World of the Future." The following eight areas identified at the symposium collectively provide the direction that should be taken in meeting the education needs for the industrial renaissance. [1]

- Enhance the prestige of manufacturing as a profession and as an intellectual challenge.
- Involve, once again, the top management of our corporations in the process of production and quality.
- Break down the artificial barriers that exist between design and manufacturing.
- Increase the interaction between industry and universities in manufacturing engineering education and research.
- Provide economic incentives from federal, state, and local governments.
- Share information on what can be and is being accomplished.

The issue is simply this: the academic community must develop curricula in manufacturing that appeal to the better students, and industry must provide intellectual challenges and financial incentives that will attract these students to choose careers in this field.

Recent strong demand from industry for graduates who can assist companies in absorbing and implementing modern technology has resulted in a remarkable response from the academic community. Recognizing the time lag (generally 5 to 10 years) and costs to establish viable undergraduate manufacturing engineering departments, most educational institutions have chosen to first initiate programs in manufacturing engineering at the graduate level. The sequence of first establishing a graduate degree program and later developing an undergraduate degree program has been followed many times in engineering education. This sequence is based on the principle that research leads curriculum development. If industry continues to press for change, there may be a major growth in undergraduate programs in manufacturing engineering. These may emerge either as options in existing departments, e.g., mechanical, electrical, or industrial engineering, or as separate departments having their own identity.



Professor DeVries is currently serving a two-year term as Program Director of the Manufacturing Systems Program at the National Science Foundation's Division for Science Based Development in Design, Manufacturing, and Computer-Integrated Engineering. He is on leave from the University of Wisconsin-Madison, where he is director of the Wisconsin Center for Manufacturing and Productivity.

Industry is seeking two types of engineers at the post graduate level. In the first group are those who want to pursue a career with a relatively narrow focus (e.g., research). Such engineers, who will become specialist in some aspect of the company's products or services will continue to be educated primarily in the traditional engineering departments. In the second group are students who have sufficient breadth to be highly productive in the design, development, implementation, operation, or management of modern manufacturing systems. These latter individuals, who will generally end their formal education with the masters degree, are appropriately educated in the emerging manufacturing systems engineering curricula. In addition to hiring new graduates, industry is recognizing the need to update the technical capabilities of valuable engineers who are presently employed in manufacturing or who wish to move into manufacturing from other areas. These engineers will also be best served by programs in manufacturing systems engineering.

An Industrial Initiative

The IBM Corporation recognized early the critical importance of the availability of suitable academic pro-

grams in manufacturing systems engineering and the need for financial support to accelerate their development. In September 1982, IBM announced a fifty million dollar grant program, including both cash and equipment, to help the education community develop and update curricula in Manufacturing Systems Engineering (MSE) [2].

IBM decided to fund two proposal types: one to develop graduate Master of Science curricula in Manufacturing Systems Engineering; the other to obtain CAD/CAM systems in support of MSE education. Within two months of the announcement date, over 150 schools submitted preliminary proposals seeking support to establish MSE curricula. In addition, there were 112 separate proposals submitted for CAD/CAM equipment.

Following a comprehensive review process, curriculum grants of approximately two million dollars each were awarded by IBM to the following five educational institutions:

Georgia Institute of Technology – Atlanta, Georgia
Lehigh University – Bethlehem, Pennsylvania
Rensselaer Polytechnic Institute – Troy, New York
Stanford University – Stanford, California
University of Wisconsin – Madison, Wisconsin

In addition, CAD/CAM equipment and software grants of approximately two million dollars per system were awarded to a total of 22 colleges and universities, including the five curriculum grant schools.

One of the most significant results of the IBM grant initiative was that the majority of the institutions submitting curriculum proposals proceeded to develop programs even though they did not receive IBM support. This represents a dramatic turnaround in academic attitudes toward the importance of manufacturing engineering.

A common attribute of the graduate level manufacturing systems engineering programs is their interdisciplinary nature [3]. In the current MSE programs, the participating groups typically include several engineering departments, the Business School, the Computer Science Department and, occasionally, other physical science departments. Individual curricula show a great deal of variety, reflecting the different philosophies of the universities.

All of the schools built their MSE programs around a basic set of common subjects which are usually referred to as core courses. These core courses were designed to provide students with a fundamental understanding of the major aspects of manufacturing systems engineering.

Elective courses complement the core courses in MSE curricula. Sometimes more than one hundred elective courses are offered by a single educational institution. Generally, all of the departments participating in the MSE program offer several elective courses. A seminar forms an important requirement of the curriculum in many schools. In most cases the schools rely heavily on industrial participation; speakers from industry collectively present a broad spectrum of viewpoints.

Manufacturing-oriented laboratories are primary elements in all manufacturing systems engineering programs. A significant percentage of the funds were used to establish new and updated laboratory facilities for computer-integrated manufacturing processes. Flexible manufacturing systems, CNC machine tools, robots, and material handling systems are prevalent in these laboratories. Other laboratories are available, or are being developed, for simulation, image analysis, artificial intelligence, interactive graphics, and VLSI design.

All of the manufacturing engineering programs recognize the need to significantly increase the interaction between the educational community and industry. Many other companies are following the example set by IBM and are donating cash and equipment for the MSE programs and by sending their employees as students and as adjunct faculty.

References

[1] Anon. *Education for the manufacturing world of the future,* National Academy Press, Washington, DC, 1985.

[2] Marvin F. DeVries and Gabor Koves. *University-industry cooperation in the USA for manufacturing systems engineering education* National Academy Press, Washington, DC, 1985.

[3] Anon. *A summary of university proposals for master's level curricula in manufacturing systems engineering.* IBM university program department, IBM Corporation, May, 1984.

[4] Marvin F. DeVries and Michael J. Redmond. *Manufacturing systems engineering at the University of Wisconsin-Madison* Proceedings of the IBM CAD/CAM Grantee Schools' Conference, Fourt Lauderdale, FL, December, 1984.

[5] Neil A. Duffie and John P. Hartwick, Jr. *Research Oriented Flexible Machining Cell* Proceedings, Manufacturing Engineering Education - Industry Conference: The Laboratory Dimension, University of Michigan-Dearborn, November, 1985.

Penn State Announces Laser Robotics Program

Dave F. Farson

The Applied Research Laboratory, The Pennsylvania State University (ARL Penn State) is establishing research and technology transfer efforts in the field of Laser Robotics.

A laser robotics research laboratory currently under installation features a 14 kW CO_2 laser will also be in operation at this facility by the end of the year. The R&D activities at the ARL Penn State research facility will support the efforts of the Johnstown manufacturing facility. The manufacturing center is currently in full-time production on various parts and components for the Navy fleet.

ARATO Update

We have received a number of enquiries about the Arato gripper which was described in the New Products section of the Spring 88 Newletter. The address on the flyer we received is : ARATO Engineering, CH - 6374, Buochs, SWITZERLAND.

Newsletter Deadline

Deadline for copy for the winter issue is January 5 1989. Please note this, especially for calendar announcements and other timely material. Again, e-mail contributions (followed up by U.S. mail in case of glitches) are great.

Are there any LaTex gurus out there who know an easy way to make three-column text with the option of one- and two-column figures? Send suggestions to Rosalyn Snyder, Managing Editor, PO Box 37694, Raleigh NC 27606, or e-mail Wes Snyder at wes@ece-csc.ncsu.edu.

Robotics & Automation Research in the Federal Republic of Germany

Rosalyn Snyder

Research and development in all phases of robotics and automation is taking place in university, industry and government laboratories. However, the research community is much smaller than in the United States, and research in robotics is often a sideline of control theory, information theory, and other disciplines. An agency of the Ministry of Science, the (DFG), like the National Science Foundation in the U.S., sponsors basic research, but in general, funds are limited for high level research which is far from industrial applications or the immediate realization of solutions to problems.

Also, there seems to be a greater emphasis on industrial applications and public-private cooperative R&D efforts than in the United States and less emphasis on pure research. The *Fraunhofer Institutes* are examples of this public-private interaction which do not have exact counterparts in the United States. Government institutes like the West German Air and Space Research Institute (DFVLR), where Dr. Gerhard Hirzinger is head of the Robotics and Automation Division, go beyond R&D to develop manufacturing prototypes and enter into licensing agreements devices such as the DFVLR sensor ball.

One of the major strengths of the German robotics program is the mechanical precision and reliability of the robots which are produced. Not surprisingly, BMW, Mercedes, and Volkswagen have a strong influence on developments in robotics, sponsoring R&D and manufacturing robots both for use in their own factories and for sale. Dr. Hirzinger finds it encouraging that medium-sized companies, as well as the giants, are beginning to show an active interest in robotics.

There is a need, Dr. Hirzinger notes, for companies which can advise manufacturers on how to use robots.

The Germans are also strong on multinational research efforts such as the European Economic Community's "ESPRIT" program which requires that agencies from two or more countries collaborate on a research project.

Dr. Hirzinger and his colleagues in industrial and university research labs are excited about the EEC space initiative, particularly since many space applications are equally suitable for industrial situations. Among their goals are development of a light-weight carbon-fiber robot which can move a greater percentage of its own weight than can the typical existing robot, and extremely sophisticated grippers equipped with multiple sensors. West Germany and other EEC countries plan to have projects aboard the next U.S. Spacelab Shuttle, currently scheduled for 1992.

Dr. Gerhard Hirzinger is head of the Robotics and Automation Division of the DFVLR, the West German Air and Space Establishment and chairman of the West German counterpart of the Robotics & Automation Council.

This article is based in large part on a February 1988 interview in which we discussed R&A research activities and goals in the German research community as compared with those in the United States.

Dr. Hirzinger provided the *Newsletter* with a synopsis of the ongoing work in his laboratory at the DFVLR and requested his colleagues at other research institutes to send us reports of their work, also. Space constraints required that we condense many of the entries, but we have included the names and addresses of the program directors. Annual reports in English and French are available from several of the institutes.

DFVLR (German Aerospace Research Establishment)
Robotics and Automation Division
Oberpfaffenhofen, 8031 Wessling/Obb Head: G. Hirzinger

A major current research area is the development of robot sensors and techniques for on-line sensory feedback. Robot sensors developed by the group include: the first six-axis wrist force sensor to become commercially available in Europe; the "sensor-ball", a sensor-based six degree of freedom hand "joystick" for teleoperation and animation of 3D computer graphic objects; a miniaturized laser range finder based on triangulation; a

ring shaped instrumented compliance, and the DFVLR multisensory gripper, which contains 9 range finders (one being a scanner), a stiff and a compliant force torque sensor and tactile arrays in the fingers.

Sensor-based robot path generation and refinement has been the basis for DFVLR's proposal to fly a robot technology experiment, ROTEX, with the next spacelab flight. A small robot mounted in a spacelab rack will be equipped with DFVLR's multisensory gripper and will not only perform automatic operations including assembly, but will also allow for sensor-based teleoperation on board and teleoperation from the ground via predictive computer graphics. Several German robot institutes have joined this project as well as NASA's Jet Propulsion Laboratory.

Laboratory for Machine Tools and Operations Research of Rhineland-Westfalia (WZL)
RWTH Aachen, Steinbachstr. Block 53/54, D-5100, Melaten Nord. Director: M. Weck

Current research activities are in the following areas:

- Development and Design of Handling Devices

  Analysis and Optimization of the Load Deflection Response of Industrial Robots

  Measurement and Analysis of Industrial Robot Characteristics Design of Industrial Robots

  Tools and Tool-Changing Systems for Industrial Robots: The WZL has been engaged in developing tools and tool-changing systems since robot technology was first introduced. Screwers, polishing tools and grippers for sensitive, easily-bent, differently-sized, and complex-shape parts have been developed.

- Robot Programming

  Programming Tools: New methods based on intelligent sensor systems are being developed for effective in-process robot programming. Power-feedback operating systems permit user-oriented motion control, for example, when complex paths are input for processing steps in automated polishing or snagging systems. Hand-held orientation-compensated joystick controls make it possible to guide the robot reliably from any operation position. In addition, mechanical or inertial measuring systems enable robot programs to be generated automatically. Programming times on the actual robot can be reduced considerably.

  Off-Line Robot Programming: Off-line programming techniques based on problem-oriented programming languages, and simulation and modelling tools are being developed for efficient programming of industrial robots and tested and optimized in close collaboration with industry. These tools form the basis for realization of software packages enabling action sequences for industrial robots to be planned automatically with the aid of artificial intelligence techniques.

- Planning and Development of Flexible Automated Production and Assembly Systems

The concept underlying this research envisages linking of two differing components of production. The aim is to integrate flexible production of individual components from design (CAD) to fabrication with the production and assembly of batch components in a single system.

Research Center for Information Theory (FZI)
Haid- Und Neu-Str. 10-14, D-7500 Karlsruhe Director: Paul Levi

The department for "Technical Expert Systems and Robotics" of the FZI has about 18 full-time scientific members. Current projects and work areas include:

- Planning module for autonomous vehicles (synchronization of distributed planning in a traffic environment)
- Model-based navigation techniques for autonomous vehicles
- Expert systems for realtime application in a CIM environment (integration of maintenance, fault diagnosis, and quality control).
- Blackboard-based expert system for image processing (use of symbolic object descriptions to process primitives such as edges and segments)
- Expert system for cell planning (configuration of autonomous cells for sheet metal treatment)
- Planning of assembly sequences and of a control system for robots
- 3-D vision system
  - Multi-sensor system with laser-scanner and CCD-camera based on a real time multiprocessor system
  - Model-driven fusion of distance and intensity images industrial parts
  - Integration of 3-D CAD models into vision systems

- Route, cross motion, grasp and fine motion planning for robot systems

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University of Karlsruhe
Institute for Real Time Computer Control Systems and Robotics

P.O. Box 6980 Kaiserstr. 12, 7500 Karlsruhe Directors: U. Rembold and R. Dillmann

The various research projects of the institute are concerned with the use of control computers to automate manufacturing processes and quality control systems. Of particular interest are robotics, autonomous vehicles, the use of AI tools for planning and controlling of manufacturing operations, and software tools for the design of automation system. Current research is concentrated in the following areas:

Robotics: The aim of the robotics activities is the development of planning and programming tools for advanced, intelligent robots which will be guided by complex sensor and vision systems and special computer architectures. In addition the robots will be equipped with dextrous hands to efficiently perform assembly operations. Within the framework of this research project an autonomous mobile robot is being constructed.

The Karlsruhe Autonomous 2 Arm Assembly Robot (KAMRO) A global control system will direct the autonomous robot to fetch workpieces from parts storage, transport them to a workbench and perform an assembly operation. The robot will be controlled by several expert systems and supervised by hierarchical sensor system.

Planning Tools for the Design of Automation Systems This research is concerned with software engineering methods for automation systems. The individual projects are:

- A user oriented system for requirement specification
- A computer aided planning tool to generate man-machine interfaces
- Graphical editors to assist the requirements specification
- A documentation system for the generation of specifications

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University of Dortmund
Institute of Robotics Research

Frauenstuhlweg 31, D-5860 Iserlohn (vorl.) Director: E.Freund

Major research topics include development of new methods for the control of complex multi-robot systems as well as related realizations and applications. These topics are based on former and current research results of the Institute in the field of fast control, online collision avoidance of robots, real-time problems in sensor-guided path control. and the coordination of large multi-robot systems. A long-term objective is development of autonomous multi-robot systems (including mobile robots) based on various hierarchiacal control levels.

GKSS Research Center Geesthacht GMBH
Institute for Construction Technology

Max-Planck-Strasse, 2054 Geesthacht Directors: E. Aust, G.F. Schultheiss

A comprehensive underwater R&D program *GUSI (GKSS-Underwater- Simulator)* focusses on underwater welding, cutting and conservation, including testing techniques and guidelines for safety. Development of computer-aided handling systems like robot- and orbital-systems, which in the first step are used in unmanned tests under hyperbaric dry conditions of a habitat up to 120 bar.
Presently, three robot-systems have been modified for these special boundary conditions. One robot is mainly used for automatic MAG-welding of specimens. The other two, more advanced robot-systems are presently used for abrasive water jet cutting and for sensor guided welding, one of them also successfully tested in helium atmosphere at 110 bar. The development of an underwater wet working robot-system within a joint program of GKSS and INTERATOM is ongoing. It is planned to continue with a computer-aided, depth-independent, and wet working robot-system for subsea work down to 1200 msw.

Univ. der Bundeswehr, Munich
Aerospace Engineering Dept.
Institute for System Dynamics and Flight Mechanics

Werner-Heisenberg-Weg 39, D-8014 Neubiberg Director: E.D. Dickmanns

Activities concentrate on dynamic scene analysis and motion control by machine vision. A 4D-integrated approach to dynamic vision has been developed exploiting spatio-temporal world models for real-time image sequence understanding. 3D-

shape descriptions, dynamical models for the motion of and around the center of gravity, and the laws of perspective projection (forward!) are used in conjunction, to arrive at a recursive least squares state estimation including the spatial velocity components, even though only the last image of the sequence only has to be processed each time. Prediction error feedback is used for bypassing the non-unique inversion of the perspective projection.

Three application areas have been investigated with real-time image sequence processing by custom-made hardware, and 0.1 sec cycle time:

- Planar docking of a reaction-jet-propelled air cushion vehicle with a 3D-partner (satellite model plant)
- High-speed road vehicle guidance (5-ton van with speeds up to 60 mph)
- Aircraft landing in a hardware-in-the-loop simulation (approach speed 60 - 70 m/s).

The Fraunhofer Institutes

Fraunhofer-Inst. for Information and Data Processing
Fraunhofer Str. 1, D-7500 Karlsruhe 1
Directors: H.-H. Nagel, H. Steusloff

Research and Development topics at the Institute include:

Robot Joint Control: Tools for robot modelling and identification, development and implementation of innovative control concepts, professional robot control cabinets (hardware + software), automatic calibration, performance evaluation by laser triangulation

Sensory Feedback Control: Application of vision sensors and force/torque sensors, development and implementation of knowledge-based single and multi-sensory feedback control, application to manufacturing tasks

Visual Sensors: Design and realization of image processing units; integration of visual sensors in robotic manufacturing cells; image interpretation; 3D object recognition and position, automatic acquisition of image interpretation of 2D pictures to create 3D CAD models; image sequence analysis: motion detection, collision avoidance, 3D reconstruction of objects; stereo motion; visual sensors for robot arc welding; sensors for robot working area surveillance.

Autonomous vehicles: Personal vehicle automatization: controlling a vehicle by sensor information; visual sensor for road and obstacle recognition; navigation; knowledge representation of the vehicle environment

Fraunhofer-Inst. for Production Technology and Automation
Postfach 800 469, Nobelstrasse 12, D-7000 Stuttgart 80
Director:Hans-Jurgen Warnecke

The central concern of the research and development activities of the institute are organizational and technological problems within the production area of industrial companies. A major consideration in the development and application of flexible manufacturing and handling systems (particularly industrial robots) is high quality and an economic and cost effective manufacturing process.

The Institute's's current work is in four broad areas:

- Corporate planning and control
- Production processes and surface technology
- Automation
- Quality technology and control.

Work at the Institute in the area of automation includes the following topics

- Industrial robots and assembly systems
- Handling and industrial robot systems
- Process and plant technology
- Technical administration
- Robot systems and sensor technology

Fraunhofer-Inst. for Production Systems and Design Technology (IPK) Berlin
Pascalstrasse 8-9, 1000 Berlin 10 Director: G. Spur; R&A Contact: U. Kirchhoff

Research and development in the Planning Department is oriented to computer integrated manufacturing. Projects are worked out in close contact with producers and users of new technologies such as robot integration or flexible manufacturing cells. Points of main emphasis include:

- Planning of flexible automated manufacturing and assembly systems

- Computer simulation for planning and optimization of production systems
- Development of information- and material-flow systems adapted to specific tasks
- Task related design of robot systems and components
- Application planning for industrial robots
- Prototyping and pilot installations in the laboratory

Research and Development in the Robotics Department is oriented to control design for industrial robots and programming technologies. Besides the terrestrial manufacturing area, there are ongoing projects in the fields of Automation and Robotics in space and off-shore. The main research topics are:

- Interactive and automatic robot off-line programming
- Control of multi robot systems
- Parameter identification procedures to increase the absolute positioning accuracy of robots
- Sensor-based control systems
- Force and position control (hybrid control)
- Real-time path planning algorithms
- Control procedures to increase the dynamical behavior of robots and control of large flexible manipulators

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Technical University of Munich
Postfach 20 24 20, 8000 Munich 2
Automatic Control Engineering Laboratory
Director: Gunther Schmidt

The focus of our research is to increase autonomy in robotic systems through advanced methods of information processing. Current projects include:

- Small parts assembly in flexible cells and robotic mobility within a factory environment. A smart universal gripper designed at the laboratory has proportional control of finger opening and applied force as well as two additional degrees of freedom for performing fast and precise corrective motions. Sensor information is provided by miniaturized 3D-force vector sensors in each finger. The gripper controller together with other intelligent subsystems is connected to the cell controller through a bitbus network. Fault detection mechanisms for each assembly phase are based on continuous decentralized comparison of expected and actual sensor values or time-out checks. Fault handling and fault tolerance capabilities are integrated into the assembly sequence control level.
- *MACROBE*: Development of this robotic vehicle is part of an interdisciplinary project at the University. Current work with MACROBE involves autonomous navigation combined with exploration within a factory environment. We are investigating a multisensor approach for exploration as well as the updating and application of hierarchically ordered geometrical knowledge bases necessary for mission planning, navigation and piloting. A main sensor is an active 3D-range imaging camera based on a scanning eye-safe laser beam. The whole system is integrated in a versatile test environment with graphic support for development of algorithms for various autonomous vehicle operations.

Institute B for Mechanics
Director: F. Pfeiffer

This institute, also at the Technical University of Munich, is involved in both teaching and research. Lectures and research are focussed on dynamics and control of mechanical systems. A lecture on the dynamics of manipulators is given for upper level students.

Main research topics are nonlinear vibrations and non-rigid multibody-systems with applications in the fields of robotics, drive trains and rotor dynamics. Robotics activities include theoretical and experimental work in *trajectory planning, dynamics and control of elastic robots, active control of elastic vibrations, and force control of elastic robots.*

Technical Univ. of Braunschweig
Institute for Control Theory
Hans-Sommer-Strasse 66, Postfach der tu 3329, 3300 Braunschweig Director: W. Leonhard

Robotics research activities at the Institute are in six general areas:

Mathematical modelling and simulation of robot arms : general models which are independent of arm kinematics, nonlinear drive train modelling, and real-time simulation.

Trajectory generation : off-line and on-line generation of continuous paths in Cartesian coordinates with independent specification of speed and optimization of speed along the path with respect to (a) total time of motion and (b) limiting of jerk

New drive train concepts for robots : synchronous and induction motors with field-oriented control

High performance joint control: fully digital position and speed controllers using digital signal processors, control of the true joint position using encoders at the gearbox output, and active damping of oscillations.

Adaptive control : scheduling of controller gains from the reference trajectory, estimation of load and link parameters, self-adjusting controllers, and nonlinear feedforward using inverse models.

Sensor-based control : use of inertial sensors (acceleration transducers and gyroscopes) for active damping and sensing of true arm speed, and accurate path following in Cartesian coordinates using optical sensors.

University of Hanover
Institute for Manufacturing Technology
Schlosswender Str. 5, 3000 Hannover 1
Director: Hans Kurt Tonshoff; Contacts for robotics: H. Jonocha and Dipl.-Ing. U. Gerstmann

Among the ongoing research projects are

Mechanical Design: (1) development of stiff as well as minimum backlash drive systems, to improve accuracy and dynamic behavior, and (2)investigation of light structures made from thin standard aluminum profiles reinforced by fiber composites with the goal of improving speed and simplifying robot manufacturing.

Controls: (1)development of user friendly off-line programming systems and investigation of knowledge-based systems for automated assembly planning in small batch size production, and (2)real time image processing and control strategies for multiple sensor systems

Development of Peripheral Devices: (1)A special purpose gripper simultaneously unloads multiple stacks of cardboard sheets. Thirteen sensors are required to guarantee safe operation in case of displaced stacks. (2)A system which self-aligns ferromagnetic workpieces in a magnetic field, avoiding expensive sensors. Among the remaining few stable workpiece positions the robot determines the actual position by means of a low cost optical sensor.

Underwater Robotics : Basic investigations of drive systems, sealings and controls in high pressure and wet environments. A tool changing system was developed for depths up to 200 m below mean sea level. Currently a hydraulic underwater manipulator is under development. Unlike other underwater manipulators it will be equipped with rotational displacement sensors.

University of Duisburg
Institute of Measurement & Control
Postfach 10 16 29, D-4100 Duisburg 1 Director: P.M. Frank

A major research goal is development of a tracking multi-sensor head for guidance and control for stationary and mobile robots, which is equipped with LASERS and CCD-cameras.
Research activities:

Multi-sensor head control

Image processing: Fast on-line detection of moving objects for robot control in assembly tasks, using information provided by the tracking multi-sensor head, and generating reference trajectories for the sensor head and robot

Robot control: Theoretical investigations of algorithms for robot-joint control which are robust for the entire robot working range and varying loads. Development of pole placement techniques for robust nonlinear decoupling and robust linear controllers. Feasibility studies for application of acceleration sensors

Trajectory planning: Development, in cooperation with industry, of new efficient trajectory-planning algorithms for the robot MANUTEC R3.

Technical Univ. of Darmstadt
Inst. of Control Engineering & Control Systems
Schlossgraben 1 Director: Rolf Isermann, Robotics Contact: H. Bruhm

Major research projects at the Institute include:

Development of a special Robot Arithmetic Processor (RAP) for fast and accurate dynamic control with compensation of nonlinear joint interactions.

Hybrid position and force control for application in machining processes and automatic teaching of complex, irregular contours.

Gripper development: A position- and force-controllable jaw gripper equipped with tactile sensors and an array of optical proximity sensors has been developed, built and put in use.

Multi-sensor fusion (integration of information from gripper-mounted sensors, wrist force/torque sensor and a vision system) and application of knowledge-based techniques for high level, intelligent action planning (e.g. knowledge-based robotic assembly).

Intelligent path planning and collision avoidance for robots with redundant joints: Obstacle and free-space representation techniques, search strategies and solution methods for the inverse kinematical problem in the presence of joint redundancies and constraints due to obstacles are being studied.

Robots with cooperating arms: application studies, development of theoretical performance models and coordination strategies. A new coordination method, which is more general than the conventional master/slave strategy, has been tested in simulation and will be implemented on a bi-arm control system.

Robot simulation: development of graphical simulation tools and engineering simulation with detailed dynamical models, down to the level of sensor and motor descriptions, both for single- and multi-arm systems.

Nuclear Research Center of Karlsruhe
Institute for Reactor Development
Postfach 3640, D-7500 Karlsruhe 1 Director: D. Smidt

The robotics group of the Institute concentrates on the application of advanced robotics technology for inspection, assembly, and maintenance. Common characteristics of all projects are:

A large work volume (typically 20 m radius, with the robotic equipment carried on a transporter system)

Restricted work space requiring collision avoidance techniques to be applied both in task planning and on-line control

Redundant kinematics utilized to avoid collision with obstacles

Integration of sensor signals in the control process(force/torque, optimal triangulation, picture analysis)

Supervisory control (automatic control influenced by human interaction, manual control enhanced by supporting computer programs)

Use of CAD and computer graphics techniques for support of the remote handling operator

The principal projects are oriented towards:

Remote handling in a fusion reactor environment (man-machine interface based on real-time animation)

Semi-automatic remote assembly of flanges and similar components

Development of an Experimental Multi-Joint-Robot (EMIR) for outdoor application in the construction industry and for rescue purposes.

Australia: Robotics Education and Research

Michael Kassler
President, Australian Robot Association Inc.

An article by Prof. Mansour Eslami in the Fall '87 issue of the R&A Newsletter, "A Worldwide Survey of Robotics Education" described activities in North America, Western Europe, and Japan". When Mr. Kassler quite rightly objected to the omission of the Southern Hemisphere in this discussion he was invited to submit information about robotics education and research in Australia. Mr. Kassler's address is: Michael Kassler and Associates, Suite 2, 2 West Crescent Street, McMahons Point NSW 2060, Australia.

The focus on Australia is timely for several reasons. From 6 to 10 November 1988 the Australian Robot Association is sponsoring in Sydney the International Symposium and Exposition on Robots, an event designated the 19th ISIR by the International Federation of Robotics, and the first to be held outside the Northern Hemisphere. Also, Australia has just been granted observer status in the International Advanced Robotics Programme established to coordinate research and development of robots that can substitute for human labor in difficult or hazardous situations.

As was the case with Prof. Eslami's survey, the information which follows is based substantially upon responses from organizations approached. Our own knowledge has been used occasionally to supplement the responses received. Unfortunately, several Australian organizations actively pursuing robotics education and research and industrial R&D did not respond to our inquiries. Therefore, the picture presented here accordingly must be regarded as incomplete.

The first part of the survey covers robotics education and research activities currently in progress or planned at universities, other tertiary educational institutions, and government-funded laboratories. (With the exception of the new Bond University, all of Australia's tertiary educational institutions are financed by government.) The second part of the survey presents robotics research activities by private-sector companies and research institutes. The order of presentation in each case is geographic, starting with North Queensland and proceeding south and west to Perth.

Activities at Universities and Government-Funded Institutions

University of Queensland, St. Lucia: The Dept. of Mechanical Engineering teaches a segment on robot dynamics in the senior dynamics subject and a segment on robot programming and on use of robots in CIM systems in a final-year elective subject called "Computer-Aided Design and Manufacture." Recent Ph.D. projects include "Representation of Non-Rigid Dynamic Performance" and "Screw Theory Approach to Force-Compliant Motion". The Dept. of Electrical Engineering teaches robotics both on the undergraduate and postgraduate levels. Research activities include machine vision, pattern recognition and a novel flexible robot.

Csiro Division of Geomechanics, Indooroopilly: Research emphasis is on development of a remotely controlled mine emergency survey vehicle including robotic concepts of such as telepresence.

University of Sidney, Sidney: Current research within the Dept. of Mechanical Engineering concerns (1) software and hardware for detection and recovery of error conditions arising during small-batch flexible automated assembly, (2) optimal control of manipulators subject to constraints such as obstacles, and (3)use of contact-force information for control of insertion, surface tracking and similar tasks. The Department next year will offer undergraduate instruction in mechatronics and advanced manufacturing technology. The Basser Dept. of Computer Science and the Dept. of Electrical Engineering teaches robotics as undergraduate subjects.

University of Technology, Sydney: The School of Mechanical Engineering teaches courses in robotics and flexible manufacturing. Current R&D activity concerns development of a $2\frac{1}{2}$D vision system using small microcomputers and structured light.

University of New South Wales, Kensington: The Centre for Manufacturing and Automation has four current projects involving graphical simulation of robots using the CATIA system: (1) optimum location of a robot in a flexible manufacturing cell, (2) optimal robot work scheduling (3) computer-aided robot selection (4)off-line robot programming.

University of Wollongong, Wollongong: The Automation and Engineering Applications Centre has undertaken considerable R&D on behalf of industrial clients in various areas including automated electronic assembly, automatic assembly of can openers, stacking of ingots, and automatic packaging. Next year several

robots will be extensively utilized in various short training courses. The Centre, in association with University engineering departments, carries out research to develop new ways of making robots move both faster and more accurately and is investigating the design and construction of robot arms with novel geometries.

Australian Defence Force Academy, Canberra: The Department of Electrical and Electronic Engineering is planning to introduce robotics as a postgraduate subject.

Australian National University, Canberra: The Computer Science Department is carrying out research into robot software controlsystems to enable robots to modify their behavior as a consequence of consultation with non-technical users. Other relevant research within the University concerns the development of machine vision systems based upon biological models.

Monash University, Clayton: The Dept. of Electrical and Computer Systems Engineering has recently established an Intelligent Robotics Research Centre. This will offer postgraduate courses in VLSI systems, computer image processing, computer graphics, robot navigation, machine vision, tactile sensing, pattern recognition, dynamics and control of robots, and other topics. The Department carries out extensive research in robot vision and tactile sensing.

Csiro Divison of Manufacturing Technology, Preston: Current R&D activities related to robotics include the development of robot control software, software simulation of manufacturing operations, and machine vision.

Footscray Institute of Technology, Footscray Robotics and Automation course are offered at the graduate and undergraduate levels. Current research concerns development of low-cost microcomputer software for graphical simulation of a robotic work cell. R&D concerning image processing for robot vision systems is anticipated to begin shortly.

Gippsland Institute of Advanced Education, Churchill: A robotics laboratory for research and teaching is currently under construction within the School of Engineering, Research, in association with the University of Wollongong, has been carried out on the dynamic behavior of a SCARA robot under different velocity trajectories.

University of Adelaide, Adelaide: As part of research toward automated sheep shearing, the Dept. of Electrical and Electronics Engineering carried out research and development of ultrasonic sensors to locate the skin of a sheep through the air and fleece. Optimal trajectory planning is being studied within the Dept. of Applied Mathematics. A short course on robotics is taught to fourth-year students in that Department. Next year, robotics will be a topic in a first-year course called "Mathematics Applications".

University of Western Australia, Nedlands: The Department of Mechanical Engineering carries out an extensive program of research toward automated sheep shearing and has built novel special-purpose robots and computer-controlled manipulators for this research. The robot's shearing actions are guided by extensive software

Calendar(cont.)

Date	Event	Place	Sponsors/Info
Dec 5-8, '88	2nd Int. Conf. on Computer Vision (ICCV)	Tarpon Springs FLA	IEEE Computer Society. *Contact* Ruzena Bajcsy, Univ. of Pennsylvania, Dept. Computer & Information Science, 200 S. 33rd St., Philadelphia PA 19104-6389
Jan.31-Feb.2, '89	NASA Conf. on Space Telerobotics	Calif. Inst. of Technology, Jet Propulsion Lab., Pasadena, CA	*Contact:* G. Rodriguez, JPL, (818)354-4057.
Feb, '89	SME Conf. on Robotics in Aerospace	Anaheim CA	Robotics International of SME *Contact:* Lori Navalta, Society of Manufacturing Engineers One SME Drive, PO Box 930, Dearborn, MI 48121.
Mar 13-16 '89	3rd Topical Meeting on Robotics & Remote Systems	The Charleston-Omni Hotel, Charleston SC	Amer. Nuclear Soc., U.S. Dept. Energy, Robotics International of SME *Contact:* Joseph S. Byrd, Gen. Chair, E.I. Du Pont de Nemours & Co., Savannah River Laboratory, Aiken SC 29808 Tel:(803)725-3527 (FTS)239-3527
March 20-22,1989	IEEE Workshop on Visual Motion	Irvine California	*Contact:* Ellen Hildreth, Artificial Intelligence Lab., 545 Technology Sq., Cambridge, MA 02139, or Ramesh Jain, Elect. Eng. & Comp. Sci., Univ. of Mich., Ann Arbor MI 48109-2122.
March 27-April 1, 1989	Applications of AI VII	Orlando, Fla.	IEEE Computer Soc. and Systems, Man, & Cybernetics Soc., and Int. Soc. for Optical Engineering (SPIE) in coop. with IEEE Computer Soc.. See **Call for Papers**

models of sheep. The Dept. of Computer Science and offers two courses in robotics and machine vision, which include study of mobile robots, edge detection, and parallel vision algorithms.

Research activities relating to robotics also are being undertaken in several other tertiary institutions, including the Queensland Institute of Technology, the Chisholm Institute of Technology, Curtin University, the Royal Melbourne Institute of Technology, the University of Melbourne. Canberra College of Advanced Education, South Australian Institute of Technology, The Levels

Research Activities in Private Companies

Sugar Research Institute, MacKay: A robotics system using a Kawasaki PH560 robot to automate measurement of the content and density of sugar in samples of "juice" from cane consignments is under development. The robot controller must cope with unpredictable sample arrival times as well as many laboratory tasks such as: insertion of filter paper into funnels; washing and drying vessels; pouring exact sample quantities; and adding and mixing various chemicals.

Apparel Robotics Limited, Kingsgrove: Research is underway to develop an automatic sewing workstation based upon a novel gripper mechanism that can pick up pieces of cloth singly from a stack without the cloth drooping.

Robo Foods Limited, Sydney: The company is developing automatic methods for acquiring, inspecting, manipulating, cutting and packing various natural and processed foods.

GSA Technology PTY Limited, Niddrie: The company is developing a totally digital DC servomechanism for robots and CNC machines that will sense and control position, velocity and torque.

John Hart PTY Limited, Clayton: The company plans to manufacture gantry robot systems. Preparatory research and development includes (1) dynamic analysis of robot structure, (2) a novel gearbox assembly, (3) the development of special aluminum castings for the gearbox and the main horizontal axis carriage, (4) development of a proprietary range of frictionless bearing trackway/rack combinations, and (5) a novel closed circuit counterbalancing system for the vertical axis. Both as a designer and developer of automation systems and as the Australian agent for GMF Robotics, the company carries out R&D regarding novel end effectors and other automation system components.

Dawson Industries, Limited, Perth: The company performs R&D to enhance its product line of remotely operated vehicles to clean corrosion, marine fouling and coatings from offshore structures both above and below water.

Adept Engineering PTY Limited, Bently: With funding from the Australian Meat and Livestock Research and Development Corporation, the company is carrying out research to develop a robot system suit-

Calendar (Continued)

Date	Event	Place	Sponsors/Info
May 14-19 '89	IEEE Int. Conf. on Robotics & Automation	The Registry Resort, Scottsdale, Arizona	IEEE Council on Robotics & Automation. See announcement and related articles.
May '89	Fleximation '89: 2nd Int. Conf. and Exhibit/Workshops of Advanced American Flexible Automation Equipment and Services	Bern, Switzerland	U.S. Dept. of Commerce. *Contact:* Daniel Taher, U.S. Embassy, PO Box 1065, CH-3001 Bern Switz., Tel 031/43 70 11; Telex 912 603; FAX: 031/437 336.
May 27-31 '89	Int. Conf. on Pattern Recognition	Atlantic City, NJ	IEEE Computer Soc., PAMI TC *Contact:* Herbert Freeman, Rutgers University, Hill Center, New Brunswick, NJ 08903, (201) 932-4208
June 18-21, '89	IEEE Int. Conf. on Neural Networks	Washington, D.C.	See Call for Papers
August 14-18 '89	3rd ORSA/TIMS Conf. on Flexible Manufacturing Systems	MIT, Cambridge, Mass.	Conducted in cooperation with the IEEE Robotics & Automation Society. See call for papers.
Aug.24-26, '89	IEEE Int. Workshop on Intelligent Robots and Systems	Tsukuba JAPAN	See Call for papers
Sept. 18-21 '89	IFAC International Workshop on Decisional Structures in Automated Manufacturing	Genoa, ITALY	See Call for Papers

able for automatic boning of forequarters of beef. A major research element is to develop a force/position control system that will allow a manipulator to debone a forequarter using a knife. Bone shape models will be used together with automatic machine-vision inspection of carcasses to minimize computation. Other R&D by the company concerns robot-controlled water-jet cutting of meat.

CALLS FOR PAPERS

IEEE International Conference on Neural Networks

June 18-21, 1989, Washington, D.C.

The Conference Chair is Sun-Ichi Amari. International Chair is Rolf Eckmiller. Organizing Committee Chairs are Wesley Snyder and Allen Stubberud and Program Committee Chair is Robert Hecht-Nielsen.

Papers of 8 pages or less are solicited in the following areas:

Optical Neurocomputers	Electron Neurocomputers
Combinatorial Optimization	Network Architectures
Neural Network Theory	Neurobiological Connections
Knowledge Processing	Learning Algorithms
Novel Applications	Vision
Robotics	Self-Organization
Communications	Control
Speech Recognition & Synthesis	

Papers of 8 pages or less should be submitted to Nomi Feldman, Conference Coordinator, 3770 Tansy St. San Diego CA 92121, (Tel)619-453-6222.

ICNN's exhibits are the premier trade show of the neurocomputing industry. Approximately 40 companies and organizations will exhibit the latest neurocomputers, neural network software, and applications.

Third ORSA/TIMS Conf. on Flexible Manufacturing Systems

Massachusetts Inst. of Technology, Cambridge MA, August 14-16, 1989

Submissions should be sent by February 10, 1989 to:
Kathy Stecke: Univ. of Michigan, Grad. School of Business Administration, Ann Arbor MI 48109-1234, Tel(313)763-0485 or **R. Suri**: Univ. of Wisconsin, Industrial Eng. Dept., Madison, WI 53706, Tel(608)262-5536

IEEE International Workshop on Intelligent Robots and Systems:
Autonomous Mobile Robots and their Applications

Tsukuba, Japan, August 24-26, 1989

Cosponsored by the IEEE Industrial Electronics, and System, Man, & Cybernetics Societies, the Robotics Society of Japan, and the New Technology Foundation and conducted in cooperation with the IEEE Robotics & Automation Society. Workshop topics include:

New locomotion mechanisms
Vision and environment recognition for mobile robots
Sensors for mobile robots
Position measurement and navigation techniques
World modelling and map representation
Path Planning and obstacle avoidance
Advanced locomotion and control in real environment
Architectures for autonomous robot controllers
Man-machine interface for mobile robots
Case studies on development of autonomous systems
Applications of autonomous robots:
Factory, clean room, home, handicapped person care, in-building environment, office, hospital, maintenance use, pipe inspection, on road, off road, construction site, field, forestry, agriculture, etc.

Submissions: Submit 4 copies of an 800 word summary to: **Prof. Shin'ichi Yuta**: Robotics Society of Japan, Institute of Information Science and Electronics, Tsukuba, 305 JAPAN, Phone (0298)53-5509.

Decisional Structures in Automated Manufacturing

IFAC-CIRP-IFIP-IFORS International Workshop

Genova, Italy, September 18-21, 1989.

The aim of the workshop is to offer a forum to discuss the most recent results on developments and applications of Production Management Architectures. To assure an effective exchange of information and promote contacts among participants, a limited number of presentations will be accepted, *each representing a research group.*

The Workshop language will be English.

The Workshop topics are organized into two main areas:

- **Modules of Decision Architectures for Production Management**
  Resource Planning in Automated Manufacturing:
  Process Planning
  Quality Assurance
  Production Planning
  Activity Timing in Flexible Manufacturing Systems
  Dynamic Scheduling
  Production Control
  Robot Cell Control

- **Integration Problems**
  Open Architectures Integrating Production Planning and Control
  Manufacturing/Marketing Interfaces
  Languages and Computer Networks

Three copies of an extended abstract (4 to 6 pages, single-spaced) should be sent by **November 15, 1988** to:

Prof. Agostino Villa: Dipartimento di Tecnologi e Sistemi, di Produzione Politecnico, Torino, corso Duca degli Abruzzi, 24, I - 10129 Torino (Italy), Phone (39) 11-556 7969; Telex: 220646 POLITO I; Telefax (39) 11-556 7991

The INSTITUTE OF ELECTRICAL & ELECTRONICS ENGINEERS, Inc.

Newsletter of the IEEE Council on

ROBOTICS AND AUTOMATION

Editor: Dr. Wesley Snyder
Dept. Electrical & Computer Eng.
North Carolina State University
Raleigh, N.C. 27695-7914

Calendar

Date	Event	Place	Sponsors/Info
Nov. 2-4 '88	CAA88 : Information Technology & Factory Automation	Turin Italy	*Contact:* Mrs. Claudia Roveglia, Dipartimento di Automatica e Informatica, Politecnico di Torino, C.so Duca degli Abruzzi, 24 I-10129 Torino, ITALY (Tel: + 39 11 556 7000; Telex: 220646 POLITO I, FAX: + 39 11 556 6329
Nov 6-11 '88	SPIE Symp. on Advances in Intelligent Robotics Systems	Cambridge MA	SPIE. Sessions include "Technology Dev. for Space Telerobotics" and "Intelligent Control of Robot Systems" *Contact:* Paul S. Schenker, Cal. Inst. of Tech, Jet Propulsion Lab., 4800 Oak Grove Dr., MS 193-330, Pasadena CA 91109 (818)354-2681
Nov. 6-10, '88	"Robots: Coming of Age": Int. Symposium & Exposition on Robots	Hilton Int. Hotel, Sydney, Australia	Australian Robot Association, G.P.O. Box 1527 Sydney NSW 2001, Australia, and the Institution of Engineers, Australia. Tel (02)959 3239, FAX (02)959 4632
Nov 7-10, '88	IEEE Int. Conf. on Computer Aided Design (ICCAD)	Santa Clara CA Convention Center	IEEE Computer Soc. *Contact:* Al Jimenez, PROCASE 3130 DelaCruz Blve, Suite 100, Santa Clara CA 95054 (408)727-0714

(Continued on p. 15)

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