Newsletter of the IEEE Robotics & Automation Society

ROBOTICS AND AUTOMATION

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In This Issue

CALL FOR VIDEOS

CALL FOR VIDEOS

As a tradition of the conference, a video tape session on new and significant experimental results and demonstrations including industrial case studies, will be organized. Accepted contributions will be included in the conference video proceedings, which will be shown during the conference, and also made available to the attendees. This program is intended to enhance and complement the results presented in the regular proceedings.

REQUIREMENTS FOR VIDEOS:

- A good video should be dynamic and contain information that cannot be easily conveyed in a paper.
- Length should not exceed 2 to 3 minutes. Showing flow charts, block diagrams, circuit boards, computers, or motors is discouraged. Operators are fine if they are central elements to the concept being illustrated (e.g. in teleoperated systems).
- Narration is important. Ideas should be expressed without jargon. Music and background noise generally interfere with the presentation. Music should be avoided unless it is generated professionally.
- The purpose of the video proceedings is to disseminate technical information, not commercial promotion. For example, the obvious display of company logos must be avoided.

SUBMISSION:

Submissions consist of a 2 to 3 minute video segment (preferred formats are 3/4", Betacam or super VHS) and an information sheet including: the title of the presentation, the names, affiliations, and addresses of the authors (please identify the corresponding author), and a 200 word abstract. They should be submitted by October 1, 1993. A $1,000 prize will be awarded for the best video. Submit to the Program Chair:

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President's Message

Tzyh-Jong Tarn
Washington University

July 14, 1993

I just returned from the IEEE Technical Activities Board (TAB) Meeting in San Juan. The TAB has approved the publication of the Robotics and Automation Society Magazine. Congratulations are due to Robert Kelley, Michael B. Leahy, Jr. and Rosalyn Snyder. They spent a lot of time in preparing a proposal for the Robotics and Automation Society Magazine. Michael B. Leahy, Jr. will be the Editor of the Magazine. Anyone interested in getting involved please contact Michael B. Leahy, Jr. His address appears on the cover of this newsletter.

At the TAB Meeting, one of the new IEEE initiatives is to increase transnational participation. New IEEE centers are being established in Europe and in Asia. Currently 25% of the Robotics and Automation Society's 5631 members were located outside of the U.S. It is predicted that this will go up to 40% by the year 2000. I have received the following suggestions that are reflective of the international character of our Society.

1.To increase the representation of the AdCom members and officers from underrepresented regions; and

2.To encourage the Chapter Chairpersons in attending the AdCom meetings.

Please let me know if you have any good ideas.

This year the Annual Robotics and Automation Conference was held in Atlanta in May. From my perspective it was a resounding success. It is quite appropriate to recognize both the strong technical and financial success of this Conference, in spite of the recession. The papers were of high quality, the sessions were crowded, the receptions, banquets, and other social events were delightful. We thank Wayne Book, John Luh, and many others involved for doing such a superb job. The Society derives its income from two major sources: membership dues and surplus from the conferences sponsored by the Society. In the economic times of today, it is difficult to expect to have regular surplus. At the last AdCom Meeting held in Atlanta, the Administrative Committee voted to activate the Conference Board of the Robotics and Automation Society. This board was charged with the long range planning of the future conferences and to provide much needed continuity from year to year. Norman Caplan from the National Science Foundation has kindly agreed to serve as the first chairman of the board.

Each year the Robotics and Automation Society elects six Administrative Committee members to serve a three year term. Norman Caplan is the Chairman of the Nominations Committee for the 1994 election. Those of you who are interested in serving please contact Norman before September, 1993. Of course, a member may submit a nominating petition carrying signatures of a minimum of 25 members, excluding student members, of the Robotics and Automation Society to automatically place his/her name on the election slate.

From the Editor's Desk

Michael B. Leahy
Air Force Material Command
Robotics and Automation Center of Excellence (RACE)

Greetings and welcome to another issue of your Robotics and Automation Society Newsletter. I hope this message finds you in good health and good spirits.

The IEEE Technical Activities Board (TAB) has formally approved our publication request to expand the Newsletter to an IEEE Magazine. With that accomplished we are now formally soliciting technical articles for the Magazine. To help you determine if your research, development, and/or prototyping activities are suitable for Magazine publication, this issue includes an article on information for prospective Magazine authors. Please take a moment to review that information and consider contributing to this new enterprise.

If you want to publish in the Magazine, I encourage you to take advantage of our extended abstract preliminary review process. As with any new publication ours will go through a maturing process. Without any prior issues to serve as a guide the scope is always a little fuzzy. In anticipation of some confusion about what is and isn't an acceptable Magazine paper, we have instituted the extended abstract review process to provide quick feedback to prospective authors. This timely review saves both the author and peer reviewers time and effort.

I don't know if it is related to all the talk about the Magazine, but we have one of our biggest and most interesting Newsletter issues to date. Let's keep on building momentum as we rush toward 1994. This issue highlights several columns that I would like to see receive increasing utilization.

Debra Hoitomt is leading a very active Technical Committee on Computer-Aided Production Management and has contributed two articles.One topic overviews some of the compelling issues in the dynamic field of agile manufacturing, while the second contribution reports on her TC's recent activities and plans for the future. We need more TCs to follow that example and use the Newsletter/ Magazine as a communication conduit to the members and beyond.

From conversations with industrial systems houses and technology suppliers I know that more than just "academics" read the Newsletter and in light of the global push toward "relevant" research we need to use all the tools at our disposal to build a solid, mutually beneficial relationship between all the players in the wide field of robotics and automation.

Pat Eicker is chairperson of a committee that is chartered to assess the changing relationship between industry, government, and academia. Like Debra, he is taking advantage of the Newsletter to accomplish that goal. Information about the committee's first meeting at ICRA 93 and its goals and objectives is presented. The topics of "curiosity-driven" versus "relevant" research and interagency relationships always brings up some heated debate. I think that is healthy, and we need more of it. If the engineering community cannot come to grips with these technology driven issues and develop a recommended policy, how can we expect the politicians to do any better? Let's use the Newsletter to foster the debate. If you feel strongly about this topic, or any other affecting our society, send in a letter to the editor. Write a professional, nonpersonal, letter, stating your views. Dare to share.

The rest of the issue is full of the normal Newsletter items: conference calls and calenders, PhD abstracts, society news, and laboratory reports. I hope you find those sections interesting and informative. I look forward to your input for our next issue.

IEEE ROBOTICS AND AUTOMATION SOCIETY MAGAZINE

INFORMATION FOR AUTHORS

The *IEEE Robotics and Automation Society Magazine* publishes high quality technical articles in the areas of: prototyping, demonstration and evaluation, and on site implementation of robotics and automation systems. Submissions should emphasize creative approaches, implementation details, and lessons learned from applying mature theories to complex real world problems. The *RAS Magazine* is published quarterly. Four types of technical contributions are regularly considered:

1. ***Papers*** - Presentations of significant prototyping, demonstration and evaluation, or implementations of robotics and automation systems
2. ***Tutorials*** - Clear explanations of the technical and historical background required to appreciate how theory evolves into applications, and insights into new theoretical developments
3. ***Letters*** - Significant remarks of interest to robotics and automation systems engineers, perspectives on current technology trends, and comments on regularly published papers
4. ***State of the Shelf*** - Objective evaluations of what's new in the market

Papers and tutorials go through the same peer review process. Letters and State of the Shelf contributions go through a shorter review process to facilitate rapid publication.

A. Submission process

Prospective authors are encouraged to send an extended abstract of proposed papers and tutorials to the editor. The extended abstract should contain the following sections: background, problem statement, objective, contribution, and outline. Length should not exceed three single-spaced pages. Email or fax is preferred to facilitate quick review. After editorial board review the author will be encouraged to submit the full article for peer review or advised that his/her proposal is not consistent with the scope of the *RAS Magazine.*

Five copies of the complete manuscript with a cover letter stating the type of contribution (paper, tutorial, letter, state of the shelf) and the name and address of the corresponding author should be sent to the Editor:

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C. Style for Manuscript

Submitted manuscripts must be typewritten in English. Specific guidelines are as follows.

1. The contribution of the paper should be presented in a manner that makes it accessible to the interested robotics and automation engineering professional. Descriptions and intuitive insight and interpretation are preferred to formal mathematical development (lemmas, theorems, and proofs). Detailed mathematical derivations (over 20 equations) are not appropriate. Theoretical developments should be sent to the *Transactions.*
2. Full length submissions must be double spaced 12pt type with adequate margins and a maximum length of 32 pages including references, tables, and figures. Papers longer than 32 pages will not be reviewed without prior editor approval.
3. References must be typed double-spaced in a separate section at the end of the paper, with items referred to by numerals in square brackets. References must be completed in IEEE style. The total number of references should not exceed 12.
4. The cover page should contain the title; name, affiliation, and complete mailing address of all authors; and a single paragraph abstract which briefly and clearly describes the contribution of the paper.
5. If accepted for publication, the text of the paper must be available electronically as a standard computer-readable ASCII text file. Instructions for electronic submission will be provided when the paper is accepted for publication.

Manuscripts exceeding the specified page limits, or clearly outside the scope of the Magazine will be returned without a review.

D. Style for Illustrations

1. It is in the author's interest to submit profession quality illustrations. Drafting or art service cannot be provided by the IEEE.

2. Original drawings should be in black ink on white background. Maximum size is restricted to 21.6 by 27.9 cm. Glossy prints of illustrations are also acceptable.

3. All lettering should be large enough to permit legible reduction of the figure to column width, sometimes as small as one quarter of the original size. Typed lettering is usually not acceptable on figures.

4. Lightly pencil each figure number on the back of each original illustration. Captions should not appear on figures.

5. Provide a separate sheet listing all figure captions, in proper style for the typesetter, e.g., "Fig. 5. The error variance for the optimal filter.:

6. Contributors' photographs should measure between 1.6 cm and 9.5 cm across the widest part of the head. The overall size of the photographic paper used can be anything from passport size to 21.6 by 27.9 cm.

E. Page Charges

After a manuscript has been accepted for publication, the author's company or institution will be approached with a request to pay a charge of $110 per page to cover part of the cost of publication. Payment of page charges for this Magazine, like transactions and other professional societies, is not a necessary prerequisite for publication. The author will receive 100 free reprints (without covers) only if the page charge is honored. Detailed instructions will accompany the proofs.

F. Special Issues

The magazine will run up to two special issues each calendar year. A special issue consists of an introduction from the guest editor, and three-five technical articles. A tutorial article is highly encouraged. Individuals wishing to sponsor special issues should submit a concise package which includes the following: motivation, listing of specific topics, potential authors, proposed call for papers, and proposed editors. Special issues must also be coordinated through the appropriate society technical committee chairperson. The editorial board will review the package and make recommendations on scope and content. If the issue is tentatively approved, full papers will be solicited and then put through the normal peer review process.

G. Society News Submissions

The *RAS Magazine* also actively solicits the types of information found in the old society Newsletter. Information about conferences, workshops, new publications, research and industry, and other professional activities of the IEEE Robotics and Automation Society are invited. Newsworthy information should be sent directly to the Managing Editor with a courtesy copy to the editor (electronic format is preferred.)

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TECHNICAL COMMITTEE REPORTS

C. S. George Lee
Purdue University
Vice President for Technical Affairs

•Industry, University, & Government Cooperative

Chair: Patrick J. Eicker
Sandia National Laboratories

Background

In one form or another, intelligent machines, intelligent processes or intelligent robotics are on every list of technologies which are deemed to be important in the 21st century. Intelligent machines are important to future manufacturing, are needed for application in space, are necessary to clean up the environment, and may play a role in future defense systems.

Charter

Given this background, the Industry, University, Government Cooperative Committee (IUGCC) will:

-Assess the changing relationships within and among the three sectors - industry, government, university.
- Assess the emerging needs for research, development, and application in robotics and automation.
- Develop a "Blueprint for the Future Research, Development, and Application of Intelligent Machines and Processes" which could be recommended to decision makers in governments, industry, academia, and professional societies.

The committee sponsored a panel discussion at ICRA93-Atlanta.In id-May, plans for the IUGCC were presented to the board of directors of the Robotic Industries Association (RIA) and the board expressed strong support for the-goals.Brian Carlisle agreed to be the official RIA representative on the IUGCC. In addition, Kim Spitznagel, member of the RIA board and Director of Technology at Motorola will participate on the IUGCC.

If you would like to participate in the activities of this committee, please contact

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• Sensor Integration and Fusion

Chair: Ren C. Luo
North Carolina State University

A Call for Participation for forming a working group of research on Multisensor Fusion and Integration (MFI) through e-mail and regular mail was been initiated in May 1992. The responses have been very good.

A mini working group meeting of MFI was held on July 9 1992, during the IROS'92 Conference (1992 IEEE/RSJ International Conference on Intelligent Robots and Systems). Possible activities discussed include sponsoring a focused conference in this particular area.

A special session for Sensor Fusion and Integration was organized by Professor M. Ishikawa at the University of Tokyo and Profes-

Industry University, & Government Cooperative Committee Membership
(as of May 6, 1993)

Patrick Eicker - Sandia National Laboratories - Chair
Norman Caplan - National Science Foundation
P. Luh - University of Connecticut
P. Khosla - Carnegie Mellon University
Brian Carlisle - Adept Technology
Lothar Rossol - Trellis Software and Controls
Steve Holland - General Motors
Erik Mettala - ARPA
Jim Albus - National Institute of Standards and Technology
Debra Hoitomt - University of Connecticut
Thurston Brooks - Hughes STX
Thomas A. Owens - Cannondale Corporation
T. J. Tarn - ex officio

ICRA94 Developing Countries Travel Fellowships

Applications must be postmarked October 1, 1993 for the Developing Countries Fellowships offered by the Robotics and Automation Society. The fellowships include travel assistance of $500 and waiver of registration fees will be granted to selected applicants from Africa, Asia, Eastern Europe, and Latin America (preference given to university students).

To apply, submit a one-page letter containing: name, address, telephone and FAX numbers (if available); (2) professional affiliation and nature of work (if student, describe current level in university, major field, etc.) (3) brief description of why attendance at the conference would be beneficial to your studies and/or professional career. The letter should be sent to:

Professor George Bekey
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Univ. of Southern California
Los Angeles CA 90089-0782 USA
Tel: 213 740 7285
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International Micro Robot Maze Contest Rules

1 The robot must pass through several control points in the maze. The location of the control points for the contest will be unveiled at the contest site.

2 A robot will leave the starting point to climb up a mountain whose maximum slope is 15 degrees, passing through the selected spots in the maze to reach the goal. The layout as in fig. 1 will be prepared at the contest site. The materials of this layout will be an aluminum alloy to avoid electrostatic charge and its surface will be finished with fine aventurine so that the machine should not slip.

3 The maximum dimensions of the body are 1.0 cm x 1.0 cm x 1.0 cm.

4 Energy or control signal can be provided from cables or flexible tubes outside. However, the robot should not be pushed directly by air pressure; a stick, and so on. These cables or tubes will not be counted as part of the robot.

5 The judgement will depend on a) idea, b) possibility of miniaturization, c) achievement of goal, d) running performance, e) humor, and so on.

6 The theme is quite difficult. The work need not be decorated. It is desirable if the robot can meet the requirements with a simple structure.

sor Ren C. Luo for the International Symposium on Robotics, Mechatronics and Manufacturing Systems'92 (Kobe Japan, September 16-20,1992). Nine papers were presented in this special session.

Prof. Ishikawa and Prof. Luo jointly gave a 4 hour seminar for about 75 participants at Kawasaki City of Japan during the annual meeting of Tokyo Chapter of IEEE Robotics and Automation on December 22 1992.

Professor Luo and Professor Ishikawa organized special sessions at the IEEE Robotics and Automation International Conference in Atlanta, with 12 papers.

The International Conference on Multisensor Fusion and Integration for Intelligent Systems will be held in Las Vegas, Nevada on October 9-12 1994. This Conference will be sponsored jointly by the IEEE Industrial Electronics Society, IEEE Robotics and Automation Society, Robotics Society of Japan and The Society of Instrumentation and Control Engineers. (see announcement).

•Micro Robotics & Cellular Robots

Co-Chairs: Paolo Dario, Scuola Superiore S. Anna and Toshio Fukuda, Nagoya University

The committee will be a co-sponsor of the International Micro Robot Maze Contest (October 15,1993, Nagoya, Japan) in Cooperation with Nagoya University and others. The contest will be held in parallel with the Fourth International Symposium on Micro Machine and Human Science (October 13-15, 1993). The goal of this contest is to promote the development of autonomous micro robots.

As a first step toward autonomous intelligent micro robots, tele-operated micro robots, whose dimensions are less than 1.0 cm x 1.0 cm x 1.0 cm, will compete in a time trial contest. Each robot will be required to pass through several selected points in a maze in going from start to finish. Participants from academia, companies, private teams, individuals, etc. are all welcomed. The participants will be classified into the amateur and the professional, and the contest will be competed in each class.

All correspondences and applications should be addressed to:

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General Chairman
3rd International Symposium on Micro Machine and Human Science
c/o Inter Group Corp.
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Japan
Phone: +81-52-263-6261
Facsimile +8 1-52-263-6298

•Standards

Chair: Leonard S. Haynes
Intelligent Automation, Inc.

Chairman Leonard Haynes represented the Robotics and Automation Society at a meeting of the IEEE Metric Policy Committee. He submitted to the RA AdCom in Atlanta the latest draft of a proposed IEEE policy with regard to metrification which had been adopted at that meeting.

The AdCom, voted unanimously to support the current draft policy on metrication *provided* that the policy be modified to always allow experimental procedure and experimental results to be reported in the system in which those experiments were performed and the results measured.

A letter from Dr. Haynes to Mr. Bruce Barfrow, Chair of the IEEE Metric Policy Committee explains the Society's opposition to the draft policy in its current form:

"Metrification is a worthy goal

Proposed IEEE Metric Policy (as amended)

The IEEE will:

•1. Actively support the use of the SI metric system in electrical and electronics engineering.

•2. Use SI units exclusively to express measured and calculated values of quantity in all IEEE publications including standards.

•3. Use the current issue of IEEE Standard 268.

•4. Promote the use of SI at all levels of education.

*It is recognized that certain exceptions to this policy will be necessary (e.g. where a conflicting world industry practice exists). These exceptions must be evaluated and approved by the appropriate Institute board on an individual basis, and for a specific period of time, and reported to the Board of Directors.

CALL FOR NOMINATIONS: RA ADCOM

The Robotics and Automation Society currently has an 18-member Administrative Committee (AdCom) rotating on three-year terms. Beginning next year, we need to fill six vacant AdCom positions by election in October. Mr. Norman Caplan, Chairman of the Nominations Committee, is working closely with Professor T. J. Tarn, President of the Society, to come up with a slate of candidates for the six vacant AdCom positions. I strongly urge anyone who is interested in the affairs of the Society to volunteer himself/herself.

There are two channels to be nominated for election to the AdCom.

As stated in the Society Bylaws, anyone can be nominated with petitions signed by twenty-five (25) or more members of the R&A Society. These petitions must be received by Mr. Caplan (Address: National Science Foundation, BES, Room 1131, 1800 G Street, N.W., Washington, D.C. 20550) or me (Address: Dept. of Electrical Engineering, The Ohio State University, Columbus, OH 43210) by September 1.

It is also possible to be nominated through the Nominations Committee. Just send Mr. Caplan your updated short bio, resume and your areas of expertise. Although the Nominations Committee may not be able to nominate everyone who volunteers to the AdCom, the Society has many appointed positions that may be able to use your talent and service.

David E. Orin
The Ohio State University
Robotics & Automation Society Secretary

and it should be pursued aggressively whenever feasible, however technical accuracy and meticulous reporting of experimental procedures and results is paramount. Any author should have the right to report measurement in the system in which those measurements were made, exactly as they were reported on his or her experiment logs. To insist authors alter experimental data for any reason is inconsistent with the Society's adherence to the highest standards of scientific accuracy. The draft metrification policy, if adopted by the IEEE in its current form would compromise the scientific integrity of all IEEE publications."

At the next meeting of the IEEE Metric Policy Committee, the letter was discussed at length. Those in favor of retaining the word "exclusive" argued that the United States has delayed metric conversion for years and needs the incentive to change. No action was taken at that meeting.

With respect to the R&A Society, Chairman Haynes said the primary impact if this policy is ultimately approved by the IEEE Board of Directors is that all publications will be required to use the metric system exclusively unless a specific exception is granted.

In some fields there are well established industry practices where changes would be difficult to enforce. An example is in aviation where altitudes are always given in feet, or in power engineering where wire sizes use the AWG standard which is inch-based. To the best of my knowledge, however, this should not be the case in the R&A Society and authors should have little difficulty converting their data into SI metric system units.

In response to several requests for a representative to address the American National Standards Institute (ANSI) Computer Integrated Manufacturing Standards Board (CIMSB), Dr. Haynes will attend their next Washington meeting as a representative of the R&AS. No specific topic for the meeting was stated other than general information on current, proposed, or possible future standards relevant to robotics.

•Computer Aided Production Management

Chair: D.J. Hoitomt
University of Connecticut

Production management is concerned with all functions and methods which facilitate the transfer of raw materials into salable goods. These include but are not limited to: inventory management, material handling, routing, scheduling, and shop floor control systems.

A wide variety of production environments may be considered in automating these activities, from traditional job shops to flexible manufacturing systems.

The Computer-Aided Production Management (CAPM) Technical Committee has an orientation on practical (implementable) methodologies which can improve productivity.

Special sessions at Robotics and Automation conferences spotlight innovative techniques currently used in factories. For example, a session on practical scheduling was organized for the 1991 Robotics and Automation Conference in Sacramento, California.

In addition, computer-aided production management is complicated by the large range of dynamic behaviors associated with manufacturing systems, from arrival of new parts to machine breakdown. This year, in Atlanta, a special session was organized which focuses on managing change in manufacturing systems.

CAPM interacts extensively with many related manufacturing functions, such as assembly or process planning, which correspond to other technical committees within the Robotics and Automation Society. Therefore, joint membership(s) in one or more technical committees is natural and encouraged. The current goal of the CAPM Technical Committee is to organize a workshop at the 1994 International Robotics and Automation Conference in San Diego exploring the implications of the paradigm shift in manufacturing.

The direction of this shift increases the reliance of manufacturing on robotics and automation. The members of the Society are encouraged to contribute ideas, energy and vision toward developing relevant and timely presentations at this workshop. Initial topics for discussion include:

- Modular (or object oriented) approaches to product, software and/or machine (or robotic) design;
- System integration from customer (marketing) to product design to manufacturing to delivery;
- Standardization across heterogeneous networks and databases.

If you wish to become active in the technical committee or play a role in the workshop, please contact
Prof. D. J. Hoitomt
University of Connecticut
Electrical and Systems Engineering
Box U-157
Storrs, CT 06268
Tel: (203) 486-6306
Fax: (203) 486-1273
hoitomt@brc.uconn.edu

Judy Book, logistics coordinator for ICRA and Wayne Book, ICRA General Chair

John Luh, ICRA93 Program Chair

R&A PRESIDENTS at ICRA93: T.J. Tarn, John Jarvis, Antal Bejczy, George Saridis, and Norman Caplan

ICRA'93: Atlanta

Wayne Book, General Chairman
John Luh, Program Chairman

The 10th International Conference on Robotics and Automation returned to Atlanta with a highly successful repeat performance. Over 650 registrants attended 112 sessions presenting 448 papers on Monday, Tuesday and Wednesday, May 3-5. In addition 40 student volunteers attended in return for their assistance at the conference. Ten workshops were presented to 200 registrants on the days immediately before and after the conference. Three industrial tours to Ford, G.M. and Lockheed Georgia were also held with enthusiastic participation. Shuttle buses to a Tuesday tour of Georgia Tech were overwhelmed as registrants visited Tech's Manufacturing Research Center, the Materials Handling Research Center and the Graphics Visualization and Usability Laboratory.

Since the 1992 Conference was in Nice, France, outside the U.S. for the first time, we looked back to the record- setting 1991 Conference in Sacramento, CA, for comparisons. Over 690 registered for that conference. The 5.6% decrease in registration was much smaller than that experienced by many other conferences in this time of economic difficulty. The American Control Conference, for example, was down in registration for 1993 by 17% from 1992.

Two plenary addresses gave perspectives on the past and future of robotics and automation. Dr. Daniel Whitney of The Charles Stark Draper Laboratory related his own transition from research in robot controls to research in product design to changes in perceived needs and opportunities for robotics research. Dr. William Hamel of the Oak Ridge National Laboratory also reached into the robotic history book to give us a glimpse into the future. His perspective came from the remote handling of radioactive materials and most currently nuclear wastes.

New value was added to the conference with a floppy disk provided to all registrants containing the titles and 94% of the papers presented at the conference. This addition gives the Society a first step toward an electronic proceedings, and allows us to evaluate the utility of these nontraditional formats. All registrants are reminded that your feedback on the enclosed survey form is critical to a valid evaluation of the floppy disk, and the possibility of a CD ROM production.

The Conference Video was well received with approximately 300 copies being sold at the conference. Thirty-two segments included in the tape were grouped into seven areas ranging from design and control to applications.

For 1994 the Robotics and Automation Conference moves West to San Diego. Chairs for that conference, William Gruver and Harry Stephanou, promise a wonderful beginning to the second decade of these conferences.

Awards Luncheon

Awards abounded at the Luncheon Banquet. For the first time, a Best Conference Paper Award was given with a $1000 award. Winners of the Anton Philips Award for the Best Student Paper and the Video Award were also announced. **David E. Orin** and **George C.S. Lee** two of the seven Robotics and Automation Society IEEE Fellows, received their awards, and past presidents of the Robotics and Automation were recognized.

Following the meal and awards, former NASA chief administrator Richard Truly made brief remarks on the need for appropriate blending of human and robotic operation in space.

BEST CONFERENCE PAPER
Brenan J. McCarragher, Australian National University, and **Haruhiko Asada,** Massachusetts Institute of Technology, received the award for their paper, "A Discrete Event Approach to the Control of Robotic Assembly Tasks". Other finalists were

- **H. Peremans** and **J. vanCampenhout**, University of Ghent, Belgium, "Tri-Aural Perception on Mobile Robot"
- **J.W. Burdick** and **J. Radford**, California Institute of Technology and G.S. Chirikjian, Johns Hopkins University, "A 'Sidewinding' Locomotion Gait for Hyper-Redundant Robots
- **J. Hyde** and **M. Cutkosky**, Stanford University, "Contact Transition Control: An Experimental Study."

ANTON PHILIPS PRIZE
Ning Xi, a D.Sc. candidate in Systems Science and Mathematics at Washington University was awarded the Anton Philips Award for the Best

BEST CONFERENCE PAPER: Brenan J. McCarragher and Haruhiko Asada

ANTON PHILIPS AWARD FINALISTS: James F. Watson, Paolo Fiorini, and Ning Xi

BEST VIDEO: Toshio Fukuda and Fuminori Saito

Student Paper. James C. Schmit of Philips Laboratories presented the award, Xi's paper, "Event-Based Planning and Control for Multi-Robot Coordination" was coauthored with **T.J. Tarn**, Washington University, and **A.K. Bejczy**, Jet Propulsion Laboratory. Other finalists were

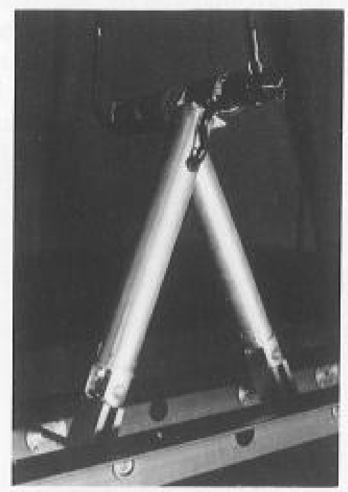
- **Kevin M. Lynch**, Carnegie Mellon University: "Pulling by Pushing, Slip with Infinite Friction, and Perfectly Rough Surfaces", **M.T. Mason**, Co-author
- **Paolo Fiorini**, University of California, Los Angeles: "Motion Planning in Dynamic Environments using the Relative Velocity Paradigm", **Z. Shiller**, Co-author
- **James F. Watson, Rensselaer Polytechnic: "A Bottom-up Algorithm for State-Space Size Estimation of Petri Nets", A.A. Desrochers, Co-author**

•BEST VIDEO

"Brachiation Robot" by **Fuminori Saito** and **Toshio Fukuda**, Nagoya University, was named the best video submission. Other finalists were

- **S-R. Oh, R.L. Hollis,** and **S. E. Salcudean,** IBM Thomas J. Watson Research Center, "The Magic Wrist: Compliant Assembly Using Magnetic Levitation"
- **David E. Orin** and **Ho Cheung, Wong**, The Ohio State University, "Quadruped Standing And Running Jumps"
- **Dr. Ronald Lumia,** National Institute of Standards and Technology "Triclops: A Tool For Active Vision"
- **A. A. Rizzi** and **D. E. Koditscheck,** University of Michigan, "Dynamically Dexterous Robotics: The Two-Juggle"
- **Kazuya Yoshida**, Tokyo Institute of Technology "Experimental Free-Floating Robot Satellite Simulator"

LOOKING AHEAD: Bill Gruver, 1994 ICRA General Chair and Harry Stephanou, 1994 ICRA Program Chair



Fukuda/Saito "Brachiation Robot"

A Discrete Event Approach to the Control of Robotics Assembly Tasks (Best Conference Paper)

Brenan J. McCarragher and Haruhiko Asada

Abstract

A new approach to process modelling, task synthesis and motion control for robotics assembly is presented. Assembly is modelled as a discrete event dynamic system using Petri nets, incorporating both discrete and continuous aspects of the process. To accomplish a desired trajectory a discrete event controller is developed. The controller issues velocity commands that direct the system toward the next desired contact state, while maintaining currently desired contacts and avoiding unwanted transitions. Experimental results are given for a dual peg-in-the-hole example. The experimental results not only demonstrate highly successful insertion along the optimal trajectory, but also demonstrate the ability to detect, recognize and recover from errors and unwanted situations.

Event-Based Planning and Control for Multi-Robot Coordination (Anton Philips Student Paper Prize)

Ning Xi, T.J.K. Tarn, and A. Bejczy

Abstract

There has been an increasing interest in the development of intelligent planner and controller for multi-robot systems. A new planning and control scheme for multi-robot coordination is presented. First, the event-based motion reference is introduced. It drives the system to achieve an optimal coordination. Unlike the traditional motion trajectory plans, which are functions of time, the new plan is referenced to events related to the system actions. As a result, the planning becomes a closed-loop real-time process. Therefore, the planner has an ability to handle some unexpected and uncertain events. After introducing the general task space concepts and combining with nonlinear feedback technique, hybrid position/force controllers are designed. The structure of the controllers are not changed for different tasks. To improve the performance of force control, the dynamics of joint motors is considered in the force control. For a given task, a task projection operator can be found for each robot with the consideration of redundancy management. The event-based planning and control scheme naturally lends itself to a distributed computing architecture. A multi-processor shared memory architecture is proposed to implement this scheme in a parallel computation. The event-based coordination scheme was experimentally implemented and tested for the coordinated control of two 6-DOF PUMA 560 robots with excellent results.

Comments on Floppy Disks and CD ROMs for the Proceedings of 1993 IEEE Conference on Robotics and Automation

•1. The service of providing floppy disks for the 1993 Conference is

____ useful, because I will use them often

____useless, because I will never use them

•2. In the next year or so, the Conference (should) (should not) provide floppy disks like the ones this year

•3. The Conference (should) (should not) replace the traditionally printed Proceedings by CD ROMS.

OTHER COMMENTS

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Name:________________________________

Date____________

Address______________________________

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Telephone____________Fax______________

Email:_______________

Please mail the completed form to
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fax: (803)656-2698

Industry/Government/University Cooperation

Rosalyn Snyder

This panel discussion was organized by the Industry, University, and Government Cooperative Technical Committee and led by Patrick Eicher of Sandia National Laboratories, the IUGC TC chair.

Jokes about the feeding frenzy sparked by the Clinton administration's announcement of a multi-billion dollar research initiative for defense conversion and dual use technology, expressions of confusion and concern about the reordering of U.S. research funding priorities, and lots of ideas about how to improve communication between the academic, government, and commercial sectors all came up in a lively panel discussion at ICRA93 sponsored by the Industry, University, and Government Cooperative Committee of the Robotics and Automation Society.

With non-U.S. nationals representing approximately a third of both RA society membership and ICRA attendance, the panelists emphasized the interdependence of the global economy and noted that because of the size of the United States, economic problems in U.S. have an adverse effect on other economies. Because of the international nature of the Robotics and Automation research community, society members have extensive expertise in private, government and university research infrastructures worldwide. Multi-national R&D projects in areas as diverse as inspection of roads and bridges to oceanic exploration address problems which have no national identity.

The panel chair, Patrick Eicker, of Sandia National Laboratories, emphasized the need for people to translate what's going on in academia to the industrial community. The Video Conference Proceedings can be one means of showing research to industry managers in terms relevant to them. He described one role of Sandia and other national laboratories as "halfway houses" to bridge the gap between the universities and the private sector.Norman Caplan of the Engineering Directorate of the National Science Foundation described the current situation as a paradigm shift, which is brand new and will be shifting for quite a while as we head away from complete separation of government and industry toward a proactive role by the federal government in the industrial sector.

Engineering research in the U.S. in the past has focused on defense and space because the Department of Defense has been the largest customer and therefore has dictated the direction of research through RFPs. The NSF has traditionally had a much smaller budget, but has the advantage of greater flexibility to fund "curiosity-driven research" and to emphasize education and human resources. However, recently, executive committees such as FCCSET — the Federal Coordinating Committee for Science Education and Technology, which have had charters but no money for some time, have obtained funding from Congress and their impact is becoming noticeable. Among the emphases of FCCSET are Agile Manufacturing, Quality Manufacturing, the Environment and Biotechnology. NORTCO (National Ocean Technology Research Corporation) may be typical of future mechanisms for government involvement in long-term high risk R&D projects in this case, utilization of coastal ocean resources for clean energy from wave motion and thermal gradients and food production through mariculture.

Peter Luh of the University of Connecticut described the principles of agile manufacturing, which emphasizes flexibility, speed and accuracy in equal measure. Commitment to agile manufacturing requires fundamental changes in the way things are made, changes perhaps as drastic as those imposed by the introduction of the assembly line. Those who are able to rise to the challenge will reap the very tangible benefits of successfully meeting the customer's needs on demand. Luh emphasized the need for researchers to take advantage of emerging technology and to improve the process of getting industrial participation in the research process. Videos, which can be used to show the development of a concept from pen and paper to a prototype model, can be useful tools to show managers of the relevance of basic research to their goals.

Luh pointed out that many government funding programs, including the $1.5 billion U.S. Technology Redevelopment Program, require university/industry collaboration. This requirement has the goal of insuring communication between the two groups through the research, development and deployment of new technologies.

However, when economic pres-

Pat Eicher and Peter Luh

New Titles

Kluwer Academic Publishers. 101 Philip Drive. Norwell MA 02061 Tel: (617) 871-6600

Robot Learning. Jonathan H. Connell and Sridhar Mahadevan, eds. T.J. Watson Research Center, IBM. 1993. *Detailed experimental results from a number of real robot systems developed at universities and research labs including MIT, CMU, Brown, University of Texas-Austin, Rochester and IBM. Includes new, unpublished material and a bibliography. ISBN 0-7923-936501*

Neural Network Perception for Mobile Robot Guidance. Dean Arthur Pomerleau, Carnegie Mellon University. 1993. *Explore the connectionist system of ALVINN (Autonomous Land Vehicle In a Neural Network) that overcomes the diversity and real time constraints inherent in vision-based mobile robot guidance. ISBN 0-7923-9365-1*

AK Peters Ltd. 289 Linden St., Wellesley MA 02191 617-236 -2101

Mobile Robots: Inspiration to Implementation. Joe Jones, IS Robotics, and Anita Flynn, MIT AI Lab. May 1993. *A guide to building mobile robots with a progression of design project of increasing complexity. ISBN 1-56881-011-3*

Technical Reports.The Robotics Institute,Carnegie Mellon University, Pittspurgh PA 15213 3890

CMU-RI-TR-92-10 Serpentine Manipulator Planning and Control for NASA Space-Shuttle Payload Servicing, H. Herman, H. Schempf

CMU-RI-TR-92-12 Fuzzy Control and Fuzzy Kinematic Mapping for a Redundant Space Robot, A. Schacherbauer, Y. Xu

CMU TR-92-13 RACCOON: A Real-time Autonomous Car Chaser Operating Optimally at Night, R. Sukthankar

CMU-RI-TR-92-16 Third Annual Report for Perception in Outdoor Navigation, C. Thorpe, T. Kanade, et al.

CMU TR- 93-01 Hidden Markov Model Approach to Skill Learning and its Application to Telerobotics, J. Yang, Y. Xu, C.S. Chen

CMU-RI-TR- 93-02 Fuzzy Inverse Kinematic Mapping: Rule Generation, Efficiency and Implementation, Y. Xu, M.C. Nechyba

CMU-RI-TR-93-03 The Terregator Mobile Robot, L. Champeny -Bares, S. Coppersmith, K. Dowling

CMUTR-93-04 Video Applications Development Platform, R. Thibadeau, R. Berger, D. Touretzky, D.Lindsay

CMU-RI-TR-93-05HSTS:Integrating Planning and Scheduling, N. Muscettola

CMU-RI-TR-93-06 An Experimental Analysis of Bottleneck- Centered Opportunistic Scheduling, N. Muscettola

CMU-RI-TR-93-07 Depth from Focusing and Defocusing, Y. Xiong, S. A. Shafer

CMU-RI-TR-93- Backtracking Techniques for Hard Scheduling Problems, N.Sadeh, K. Sycara, Y. Xiong

CMU-RI-TR-93-09 Panacea: An Active Sensor Controller for the ALVINN Autonomous Driving System, R. Sukthankar, D.Pomerleau, C. Thorpe

CMU-RI-TR-93-10 Massively Parallel, Adaptive, Color Image Processing for Autonomous Road Following, T.Jochem, S.Baluja

CMU-RI-TR-93-12IR- RAT: Infrared Remote Activity Transceiver-Universal Model, W. Sands, R. Thibadeau, D.Anderson

CMU-RI-TR-93-14 Segmenting Textured 3D Surfaces Using the Space/Frequency Representation, J. Krumm, S. A. Shafer

THESIS: System for Automated Fixture Planning with Modular Fixtures, K.H.Kim

THESIS: Agent Design for Automatic Use of a Software System: A Case Study with a Soar Agent for Mathematica, D. K. Pathak

ICRA93 Panel Discussion

sures cause companies to "rightsize" (i.e., cut staff), and large companies reduce their R&D staff and smaller companies give up the hope of acquiring such "luxuries". Academic researchers must make good use of this opportunity to become "relevant". They, however, have to avoid the temptation to follow the demand for research on "relevant problems" to the extent that they abandon the cutting edge altogether.

The major role of the academic researcher is not to solve the problems which plague industry today. Those in the private sector will do that out of necessity themselves. The private sector needs and expects academic researchers to look ahead and work on solutions to problems that are going to pop up six months or six years down the road.

In the absence of functioning crystal balls, researchers need to spend the necessary time and effort to learn the real needs of industries, especially those needs that may be laying in wait pending the solution of the immediate crisis.

The approximately 50 ICRA participants who attended the panel discussion took an active role. Some comments in the discussion were repeats of those at every RA conference for the last 10 years— the difficulties of crossing the barrier between research and application, the emphasis by U.S. industry on quarterly profit/loss statements which almost preclude long range R&D, and the publish or perish university tenure requirements that give little time or incentive for efforts at technology transfer. Nevertheless, there was a sense of excitement, optimism and purpose among the speakers that indicated a belief that after ten years and more, people outside the Robotics and Automation Society might finally be listening.

Note: For more information about the U.S. Dual Use Research Initiatives, call 1-800-DUALUSE. The deadline for SBIR proposals under the Dual Use Initiative is September 16.

The IEEE in the 21st Century: The IEEE Strategic Plan

Since August 1992, the Strategic Planning Committee and selected IEEE volunteer and staff leaders have been preparing a long-range IEEE Strategic Plan. Part I of the draft Plan will be distributed to the general membership with the *IEEE Institute*. Members can obtain copies, offer suggestions and comments via email to strategy@ieee.-org or by writing Committee Chair Henry L. Bachman, IEEE Headquarters, 345 East 47th Street, New York, NY 10017.

The eight primary goals as stated in the preliminary document are:

•**Goal 1— Globalization:**
Make the IEEE a truly global organization, characterized by (1) decentralized volunteer and staff leadership working cooperatively around the world, (2) collaborative relationships with national electrotechnical societies, and (3) involved members from all areas of the world.

•Objective 1A—Achieve international recognition of the IEEE as a global organization, complementary to the various national technical and professional societies.

•Objective 1B—Substantially increase IEEE membership in all areas of the world that have a significant capability in electrotechnology.

•**Goal 2—Information Exchange:**
Establish the IEEE as a leader in the use of technologies for high-speed communications to disseminate information products and services, enhance technical interaction among members, and improve organizational communication among the professional staff and volunteers

•Objective 2A—Develop an electronic communication infrastructure that will effectively support the dissemination of information products and services and that will also enhance the exchange of information among members, volunteers, and staff around the world.

•Objective 2B—Provide interactive electronic access to IEEE services such as membership and subscription renewal, conference registration, electronic networking, bulletin boards and forums.

•**Goal 3— Products and Services:**
Move expeditiously to the electronic dissemination of existing IEEE products and services; systematically identify opportunities for expanding the product line to take full advantage of the electronic media and broaden the markets for the Institute's products and services

•Objective 3A—Make all IEEE information products available in electronic form as quickly as possible.

•Objective 3B—Develop a business model that will aid in making sound decisions leading to sensible pricing of products so as to produce adequate income and ensure worldwide distribution

•Objective 3C—More closely match IEEE products and services to the needs of members and nonmember customers worldwide, with special emphasis on the practical applications of electrotechnology and environmental concerns.

•Objective 3D—Create a system of distributed data bases to provide customized access to IEEE information such as technical articles, complete journals, continuing education products, product catalogs, a calendar of events, news bulletins, and personnel directories.

•Objective 3E—Position the IEEE as the premier publisher of books on electrotechnology and as the publisher of choice for member-authors.

•Objective 3F— Provide an extensive menu of competitive non-technical products and services to meet the personal needs of members.

•**Goal 4— Standards:**
Achieve and maintain recognition of the IEEE as a leader in the timely generation and dissemination of international electrotechnology standards that promote expansion of the industrial base in which IEEE members are employed.

•Objective 4A—Make the IEEE a major force in the development and publication of standards and related information that serves the needs of the international electrotechnical community

•Objective 4B—Ensure that the Institute's standards development and distribution processes remain financially sound as electronic dissemination becomes predominant.

Continued on page 21

The IEEE Globalization Report

The IEEE Ad Hoc Committee for the Development of a Global Institute is now publishing an electronic newsletter to focus on the international activities of the Institute. H. Troy Nagel, President -Elect is executive editor.

Those wishing to contribute articles should send via e-mail to Barbara Ettinger, managing editor: b.ettinger@ieee.org. To subscribe to the IEEE Globalization Report

•send an email message to: listser@info.ieee.org. (The subject field is irrelevant. Enter anything)

•On the first line of the message, enter the following command: sub global.news [address]

The Space Robot Technology Experiment Rotex

Gerhard Hirzinger
German Aerospace Establishment (DLR)

ROTEX was part of the Spacelab Mission D2, on the shuttle flight STS 55 Columbia, April 26-May 6, 1993)

For the first time in the history of space flight a small, multisensory robot (i.e. provided with modest local intelligence) has performed a number of prototype tasks in most of the different operational modes that are feasible today; namely preprogrammed (and reprogrammed from ground), remotely controlled (teleoperated) by the astronauts using a control ball and a stereo-TV-monitor, and remotely controlled from ground via the human operator as well as via machine intelligence. In these operational modes the robot successfully closed and opened connector plugs (bayonet closure), assembled structures from single parts and captured a free-floating object. Particularly spectacular— these pictures went around the world— was the fully automatic grasping of the free-flyer from ground (based on real-time image processing out of the hand cameras) despite an overall signal delay of more than 6 seconds.

ROTEX Technologies

The success of ROTEX is due in large part to several key technologies:

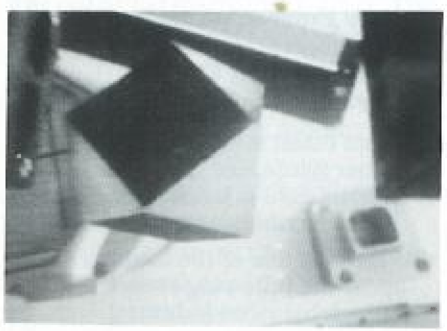


Photo taken by one of the robot hand cameras of the free-floating object seconds before capture by the ROTEX hand. (Photo courtesy DLR)

- **Multisensory gripper:**

With 16 sensors (e.g. a stiff and a more compliant optical force-torque-sensor, 9 laser range finders, a stereo camera and tactile arrays) and more than 1000 electronic components, the ROTEX gripper presumably is the most complicated robot gripper built to date. Nevertheless, it worked perfectly during the mission. None of the sensory systems heated up beyond 38° C, although they were designed for up to 70° C. The stereo images from the hand camera as well as those from the workcell camera were impressive.

- **Local (shared autonomy) sensory feedback control:**

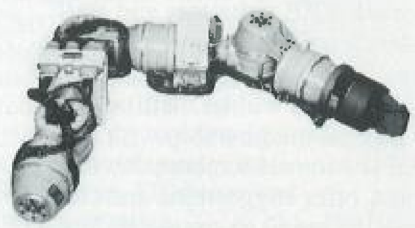
The on-board robot was able to refine gross commands autonomously by intelligent sensory processing

- **Predictive simulation:**

The powerful delay-compensating 3D-stereo graphic simulation included the robot's sensory behavior, enabling the robot and its operators to overcome the 6+ second signal delay.

In addition to the overall performance observations, the initialization phase showed interesting effects when different joint control parameters were uploaded, one of them bringing the robot near to stability margin. Due to the lack of gravity, the joints had no preloading. Thus the controllers had to compensate for backlash effects, etc.

In-flight-calibration of the robot using the finger-tip laser range finders improved its positioning performance.



The ROTEX Arm (Photo courtesy DLR)

The experiment also clearly showed that the ground control structures for future space robot applications should be *radically* changed, to allow the robot operator on ground direct access to the different types of uplinks and providing him with a continuous TV-transmission link.

Close cooperation between man (astronaut or ground operator) and machine comprising different levels of robot autonomy was the basis of the success of ROTEX. It was clearly proven that a robot system configured in this flexible *arrangement* of arbitrary and fast switching between the most different operational modes will be a powerful tool in assisting man in future space flight projects. It was impressively shown that even large delays can be compensated by appropriate estimation and pre-simulation concepts.

Technology Transfer

A number of terrestrial spin-off effects of DLR's (German Aero-

Continued on page 21

Gerhard Hirzinger

An Open Architecture Industrial Robot Controller

F. Dogliani, G. Magnani and L. Sciavicco

Modern industrial robot controllers are powerful multiprocessing computing machines, rather flexible for application development thanks to powerful programming systems. For cost reasons, however, they have very compact and optimized hardware and software architecture.

The need to compare most interesting "modern" control concepts and algorithms, proposed by academic and research community, with "classical" algorithms, implemented today in most industrial controllers, is clearly recognized in both academic and industrial worlds. However, experimenting with new control concepts or algorithms is a prohibitive undertaking even to skilled users. Documentation and software development tools that should be available to the user who is interested in such experimentation usually represent proprietary know-how that robot manufacturers do not disclose.

In view of this, the Italian National Research Council, in the frame of the national research program on robotics, Progetto Finalizzato Robotica, promoted in 1990 a research project aimed to develop an "open" version of an industrial robot controller suitable for the evaluation of "modern" control algorithms and concepts. Evaluation means to measure performances, requirements in terms of computing power, and most important from an industry point of view, robustness, reliability, and ease of tuning.

Various operating teams were involved in the project. From the industrial side were COMAU SpA (FIAT group), the Italian leading company on robot manufacturing and factory automation, and Tecnospazio SpA (joint consortium of COMAU and FIAR SpA) Italian leader in space robotics. From the academic side were Politecnico di Milano (Prof. Maffezzoni), Universita' di Napoli (Prof. Sciavicco), Universita' di Roma "La Sapienza" (Prof. Nicolo') and Universita' di Roma "Tor Vergata" (Prof. Nicosia).

The requirements for the open controller were defined jointly by the teams. Then, while the academic research teams focused on design and software implementation of control algorithms, the industrial teams started the design of modification to be introduced on the C3G-9000, the state of the art industrial controller manufactured by COMAU.

The C3G-9000 is a VME-bus-based system comprising two processing boards: the Robot CPU (RBC) and the Servo CPU (SCC).

The RBC board is equipped with Motorola 68020/68882 CPUs and with a shared memory area that can be accessed from the RBC itself as well as from other boards on the VME-bus. Tasks running on RBC accomplish user interface functions and translation and interpretation of the user's programs. The RBC drives the Operator Control panel and the programming terminal.

The SCC is a multiprocessing board with Motorola 68020/68882 CPUs and with Texas DSP. Its main functions are trajectory generation,

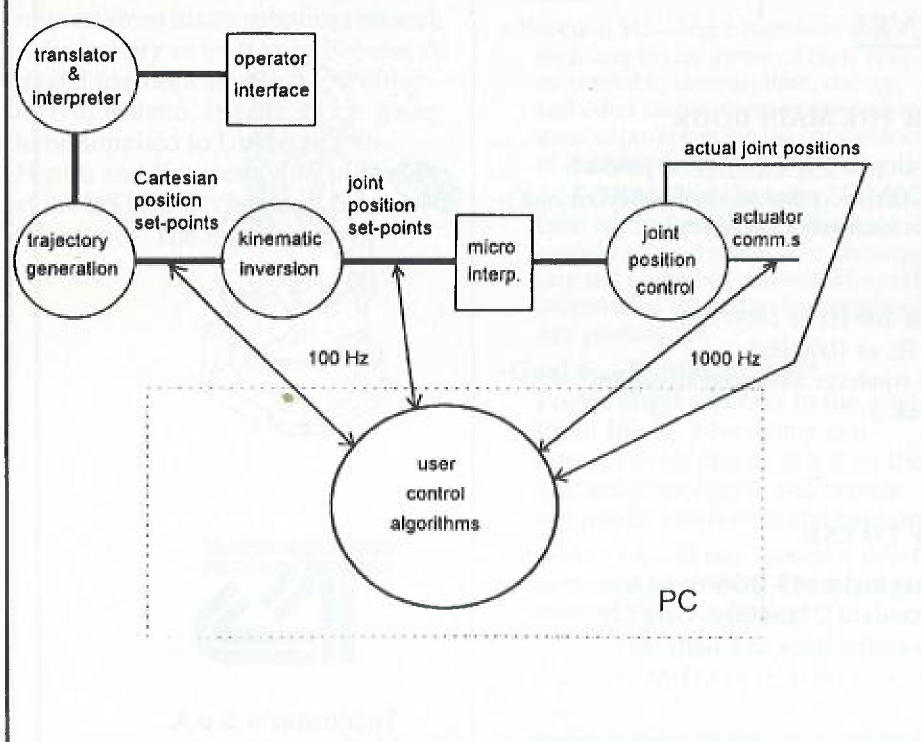


Figure 1

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both in joint and Cartesian space, kinematic inversion, micro interpolation, joint position servo-control. Trajectory knot points are updated each 10 ms, while the position servo-loops sampling time is 1 ms.

Other boards are fitted in the system for safety functions AND digital and analog I/O.

The C3G - OPEN controller

Thanks to the standard VME-bus, it is easy to perform a tight hardware integration of commercial hardware in the controller. Of course the difficult task concerns the communication and synchronization of external software processes with controller processing and functions.

As far as the hardware is concerned, the choice was to establish a bus-to-bus communication link between the C3G control unit and a standard Personal Computer. The link is established by a bus-to- bus communication adapter BIT3, consisting of two boards to install in the VME an in the PC bus respectively and connected via a parallel communication cable.

The PC and the C3G communicate by the shared memory on the RBC. Time synchronization is implemented by interrupt signal from C3G to PC. The interrupt starts the PC operating cycle, consisting of reading data from the shared memory, executing control algorithms, writing computed variables (to be actuated by the C3G itself) in the shared memory.

User control algorithms running on the PC may interact with C3G algorithms at different levels, according to chosen operating mode; data exchanged by the C3G and the PC will vary consequently. Figure 1 is a functional description of controller showing interaction and data exchange points between controller and PC software.

User control algorithms may interact with standard control algorithms either at trajectory generation level or at joint control level.

At the trajectory generation level, the user interface facilities of the C3G still remain active, and therefore they may be exploited to program robot tasks. The control algorithms on the PC may read both Cartesian (T6 matrix) and joint position and velocity set-points computed by C3G and may overwrite them. Actual command signals and joint positions may also be read, and an offset to the command signal be written.

At joint control level the PC reads measured joint positions and writes the actuator command signals (motor current set-points). Therefore the PC control algorithms completely replace the C3G algorithms.

Data exchange at joint level is at the frequency of 1 KHz, high enough for the fastest control algorithms, while at trajectory generation level it is at 100 Hz.

A test-bed for advanced robotic controls

A test-bed was installed at Tecnospazio laboratories (Milan), made up of the C3G-OPEN (with a COM-

PAQ 486 M50 - 50 MHz PC) and of a SMART 6.12R COMAU robot equipped with commercial force sensor (linked through serial and parallel lines to the PC). Various experiments have already been performed on it by academic and industrial teams. For instance feed-forward model-based, learning and hybrid control algorithms have been implemented. results will be presented to the next robotics and control community conferences.

The PC represents a powerful, easy and well-known programming environment, very rich with development tools and data analysis software. Modification of control algorithms is easy when programming with a high level language on a PC. Furthermore the PC may be easily connected to external sensors (e.g. force/torque sensor) and systems through standard interfaces at very low cost.

Altogether the test-bed combines the advantages of a powerful research tool and a system composed of fully standard industrial components.

The test-bed has won general interest from many robotics research units in Italy as well as in Europe. A model has been supplied to Politecnico di Milano, and others are going to be supplied to Universita' di Napoli and European Space Agency at the ESTEC Technology Center (Nordwijk, The Netherlands).

G. Hirzinger: The Space Robot Technology Experiment Rotex (from p.18)

space Research Establishment) space robotics work are already visible today. Just to mention one example: The 6 dof hand controllers (control balls) used during the mission by astronauts and ground-teleoperators have been redeveloped into a space control mouse for 3D-graphics, and are now distributed and manufactured under license by the company LOGITECH.

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IEEE Strategic Plan (from p.17)

•Goal 5— Education
Ensure that IEEE members have convenient and affordable access to comprehensive learning experiences that will enable them to continually update their professional competencies; enhance the IEEE's positive influence on the quality of engineering education at all levels.

•Objective 5A—Assure that IEEE members have access to affordable, high-quality continuing education programs throughout their careers.

•Objective 5B—Achieve greater influence in determining standards for electrotechnology education worldwide

•Objective 5C—Make members and their employers aware of their common need to commit time, energy, and other resources to assure continuous improvement in the competence of individuals and organizations.

•Objective 5D—Become a major influence on teachers, school guidance counselors, and students in elementary and secondary schools who seek information about the electrotechnology professions.

•Goal 6— Public Support
Foster improvements in the quality of life by advocating economic development based on the electrotechnologies and increasing public awareness and support.

•Objective 6A—Foster economic development by promoting the advancement of electrotechnology.

•Objective 6B—Promote public technological literacy

•Objective 6C—Improve the general public's image of the electrotechnology profession and its practitioners.

•Goal 7— Organization
Improve the IEEE organizational structure and business practices to take greatest advantages of available resources and ensure cost-effective responsiveness to member and customer needs.

•Objective 7A—Enhance commitment to excellence of service for members and customers in all technical and geographic areas

•Objective 7B—Reduce barriers between the IEEE's many organizational units and increase productivity by fostering innovation and interunit cooperation.

•Objective 7C—Make the greatest possible use of the expertise, energy, and dedication of the IEEE staff and volunteer leaders by creating an energizing, supportive working environment.

•Objective 7D—Develop methods for ensuring the continuity of IEEE operations.

•Objective 7E—Ensure that the professional career needs of the Institute's U.S. members are satisfied in a manner complementary to the Institute's globalization goals.

•Goal 8— Finance
Maintain a sound financial position that reduces dependence on member dues, ensures efficient management and use of financial resources, and supports the Institute's global objectives.

•Objective 8A—Develop a long-term financial management strategy for the Institute that addresses all present and anticipated needs.

•Objective 8B—Optimize the management and use of the Institute's financial and human resources

•Objective 8C—Identify and implement new income-generating programs and activities

From Robots to Design

Daniel E. Whitney
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The following is a summary of Whitney's Keynote address at The 1993 IEEE Robotics and Automation Conference, Monday, May 3, 1993

This talk will challenge the IEEE Robotics and Automation Society to ask itself if it pays enough attention to the Automation part of its name. The trend at the annual conferences as well as in the Journal has been to emphasize Robotics and de-emphasize Automation. Since there are many benefits to be gained from the combination, I will try to make this case by example as well as with some history.

A Little History

It is useful to begin by recalling last year's Keynote address, given by the director of the French Space Agency. His argument ran more or less as follows: due to the sharp and unstoppable rise in the computing power of microprocessors in relation to their price, weight, and power consumption, it is inevitable that computers and robots will replace men in space. At the very moment he was speaking, Space Shuttle astronauts were in the process of abandoning their attempt to retrieve a satellite using the Shuttle's Remote Manipulator System and preparing to retrieve it by hand. Why did this happen?

There seem to be two reasons: first, there was little documentation on the satellite itself in the region where it was supposed to be grasped. Second, it was not designed to be grasped in space, although subsequent satellites are. The failure therefore was not a failure of robotics but rather a failure of robotics and automation.

Here is another vignette from last year's conference: at the tutorial session on assembly planning. The chairman said that assembly planning is a subset of planning. which makes it a subset of artificial intelligence. Whereupon every speaker thereafter said that assembly planning was a subset of product design, a very different view.

This vignette nicely captures the difference in viewpoint between "pure" robotics and the union of robotics and automation. Such differences have often led to radically different perceptions of what robots would be able to achieve in actual use in manufacturing.

The "AI view" of the robot as a substitute person has not been borne out in industrial practice, mainly for the reason that it sees the robot as an isolated entity that should be able to function independently of its environment and therefore can be conceived and designed independently of it. The failure of the Shuttle manipulator to retrieve the satellite in May 1992, in spite of excellent training and arduous efforts by the astronauts, is evidence of the weakness of the "AI view."

The differences between the "AI view" and the "product design" view can be further illustrated by the Alvey Demonstrator project, a European Community program in the mid 1980s that attempted to create a factory robot that could plan its own assembly work. The presumed scenario was that the robot would receive a group of parts and, even if not all the necessary parts were present, would seek a suitable plan and assemble as many of them as possible, setting the unfinished assembly aside until the rest of the parts arrived, and working on something else in the meantime.

Is this a reasonable scenario? Consider what will happen: either the rest of the parts will arrive in a few seconds, in which case the robot should just wait until all are present and then use the optimal plan; or else the missing parts will not arrive for some minutes or hours, in which case it is again better to wait since - because assembly usually takes only a few seconds per part anyway - in that length of time other useful work can be started and completed. Otherwise, if many incomplete items are made, the room will soon fill with unfinished assemblies, using space and fixtures, causing bookkeeping problems, and so on. Therefore, in either case it is better to wait until all the parts are present. Note that this line of reasoning does not need to consider the robot's skill as an assembly planner. The reasoning is based entirely on the characteristics of the robot's environment. The moral, repeated many times in practical robotics, is that only the robot plus its environment is worth thinking about. Neglecting the environment removes many necessary constraints and makes valid conclusions hard to obtain. Automation is a valid and valuable environment to use for this purpose.

My Own View

I have come to this way of thinking by the route of research into robot assembly, which resulted in an appreciation for the value of understanding the requirements on robot actions that are imposed by the parts being assembled. Part mating theory led to the conclusion that in many common and important cases, parts will almost assemble themselves as long as they are gripped properly and the initial errors between them lie within certain bounds. This aspect of the theory might well be called "assembly in the small" to distinguish it from "assembly in the large" which I will define shortly.

At this same time (mid 1970s) there was a great deal of optimism about robots in industry. This optimism faded to disappointment soon after as people realized that robots were too slow and cost too much, and more importantly that products were not designed properly for robot assembly. The essential fit of robot plus environment (in this case the environment is a properly designed product) was not there.

It is now 15 years later and we know better. To create the successful robot assembly systems we see today (20 robots in a line at Sony each assembling 5 complex parts to VCR tape decks or 80 robots in a series of lines assembling all the complex subassemblies of Polaroid cameras) required complete rethinking of both products and robots. This rethinking can be called assembly in the large. While assembly in the small is a relatively controllable physics problem, assembly in the large is a system problem that combines robots, economics, detailed product design and overall product architecture. Arriving at the understanding we now have and extending it further require retaining that system view.

A Focus on Assembly

I want to dwell on assembly for a while because it illustrates these system issues so well and points to several ways that robotics and automation could come together more productively in the future. Assembly is compellingly interesting physically, logistically, and from the point of view of the product's function.

Many of the issues presented by assembly can be addressed by skills and techniques developed in robotics theory, such as kinematics, algorithms, coordinate transforms, and data structures. In one sense, everything in manufacturing happens during assembly. This is where a product comes to life, inasmuch as single parts usually perform no functions.

The links between parts often trace functional links: (assembly description) the motor is attached to the shaft which is attached by rack and pinion to the load; (functional description) when the motor turns, the load moves.

Furthermore, products can be thought of as members of families, and the architecture of the product can determine how to plan assembly so that it is easy to generate whatever family member is needed on a Just in Time basis. A number of engineering and database problems come together here, such as part tolerance stackups, part-whole relations, combinatorics, and so on.

More generally, assembly in the large permits us to see assembly in many roles other than mere part mating. These include logistics, resource mobilization, the ability of a factory to respond to outside forces, and enterprise integration. With this view in mind, one can see new ways to design products to enhance manufacturing flexibility.

Consideration of assembly may spawn ways to capture product function and relate it to product geometry during design. Finally, it may show the need for new kinds of product design tools that take account of assembly and prepare products for flexible assembly by robots.

Examples of Assembly in the Large

The examples that follow are Japanese shipbuilding, assembly-driven product design and manufacturing, and Feature-based Design for Assembly.

Japanese shipbuilding:

In the 1950s and 60s, several Japanese shipbuilding companies extended Henry Kaiser's modular shipbuilding methods from the 1940s beyond structural modules. In the Japanese method, everything became a module: structure, pipe, ventilation, larger and larger pieces of the ship, and more complete pieces that had all their interior equipment installed in the shop before being joined to the ship. Not only did every part of the ship become a module, but the shipyard's shops, equipment, and work crews became modules as well. The principles of Group Technology and Statistical Process Control were combined to create an integrated design and manufacturing method that was based on assembly as the main production step.

Assembly-based manufacturing:

This is a term I have coined to describe another Japanese company's flexible production methods. The company is Nippondenso, and the issue is to make assembled products to order by the Just in Time method in response to unpredictable

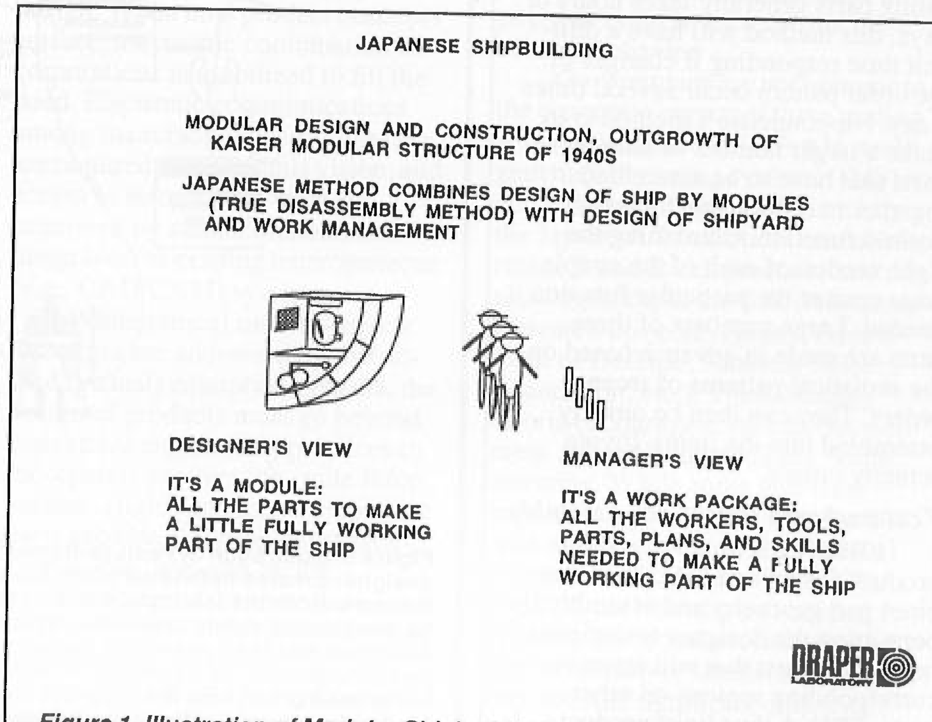

Figure 1. Illustration of Modular Shipbuilding. On the left side is the designer's view of a complete module of the ship, including all the parts, fully installed, painted, tested, and ready to be joined to similar modules on the ship. On the right is the manager's view, a work package complete with plans, tools, parts, and worker skills needed to make the module.

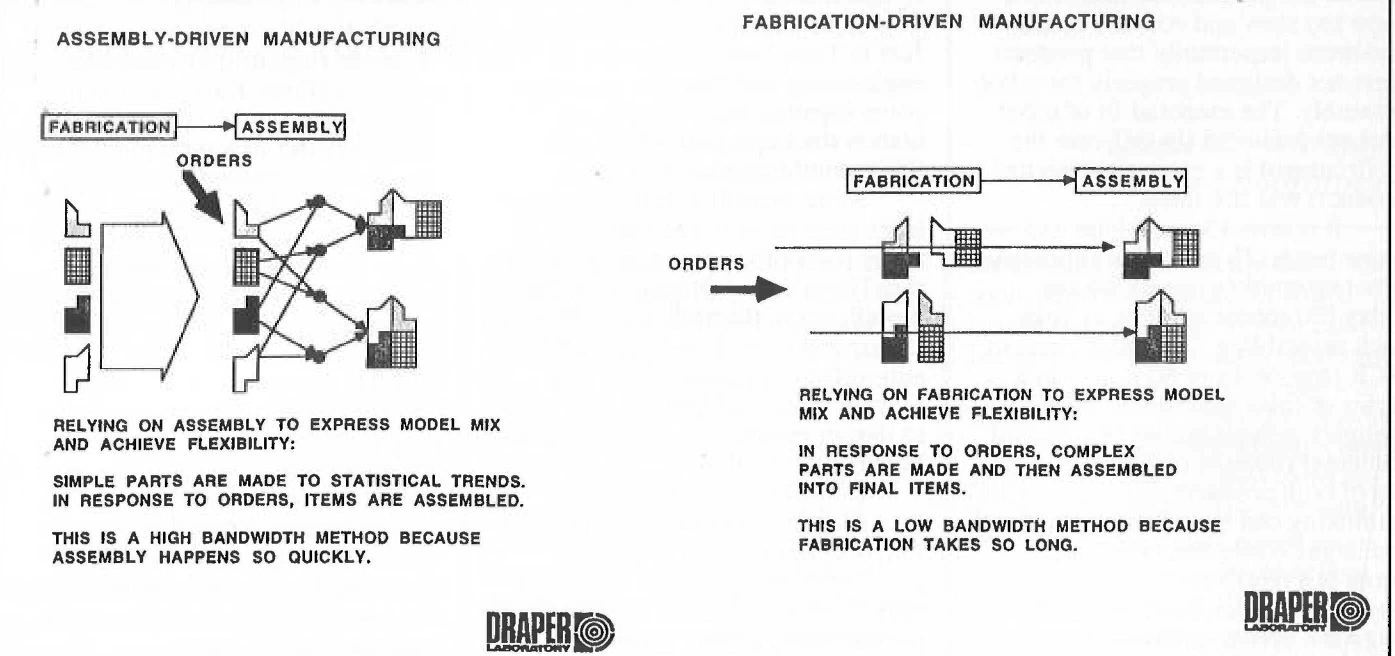

Figure 2. The Difference Between Fabrication-driven Manufacturing and Assembly-driven Manufacturing

orders from Toyota. The method one might normally use is to make a wide variety of complex parts that each contain the different features Toyota needs, and put them together when they are needed. Since fabricating parts generally takes hours or days, this method will have a difficult time responding if changes in the order pattern occur several times a day. Nippondenso's method is to make a larger number of simpler parts that have to be assembled together in order to perform the desired function. Combining the right version of each of the simple parts creates the particular function needed. Large numbers of these parts are made in advance based on the statistical patterns of recent orders. They can then be quickly assembled into the items Toyota actually orders.

Feature-based Design for Assembly

FBD-A is a new approach to product design and CAD that combines part geometry and assembly by permitting the designer to designate regions on parts that will assemble to corresponding regions on other parts. FBD-A thus links product design with individual part design

Continued on p. 26

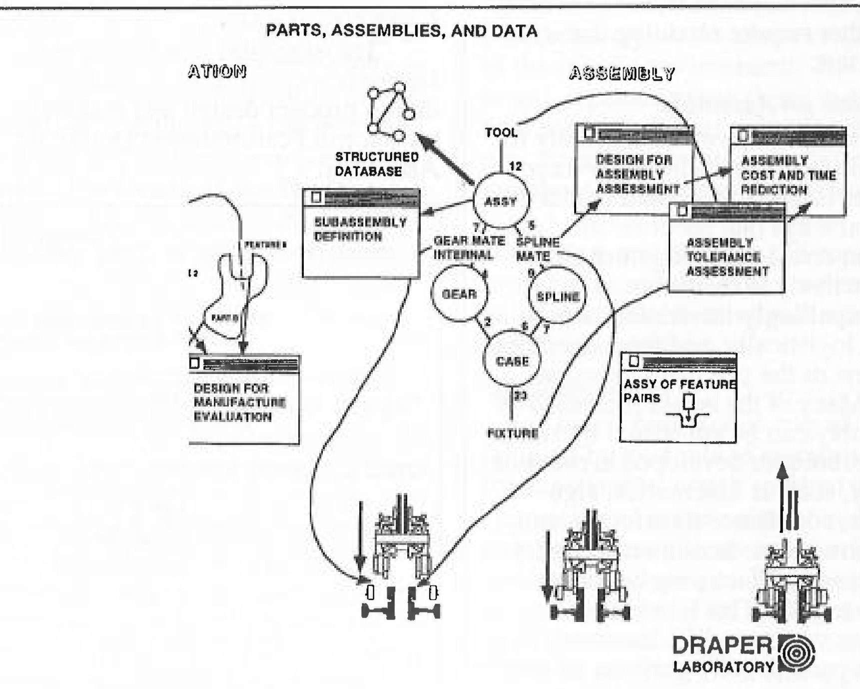

Figure 3. Illustration of Feature-Based Design for Assembly. On the left, the designer creates individual parts from arbitrary geometry plus assembly features. Both the fabrication and assembly aspects of these features can be considered at this time using special design software. As the parts are designed and their assembly features are linked, a database can be built up that captures the assembly information concerning which parts assemble to each other, how the parts are located relative to each other, and what kinds of assembly actions are needed to mate them. On the right, the issues surrounding assembly of pairs and groups of parts can be considered, such as breaking up the product into subassemblies and understanding different assembly sequences.

Paradigm Shifts in Manufacturing

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Two independent studies of future factories have detected a paradigm shift from mass production systems, as typified by the assembly line, to customized manufacturing, which relies heavily on automation to manufacture a high variety of items. Although the two studies were conducted in the U.S. and Japan, respectively, the conclusions drawn appear to have broad applicability. In general, a paradigm shift implies that manufacturing is moving through a period of rapid change. This article will identify the key factors motivating these changes, and explore implications for researchers and practitioners.

According to a five-year study of future factory systems performed by the Development Industry Association in Japan (Suda, 1989), mass produced items are not meeting the needs of numerous small demographic groups of consumers, which together make up sizeable market shares. These consumers provide short-term advantages to niche producers, who take profits while a trend is popular. In effect, global competition is forcing corporations to confront the weaknesses of inflexible mass production lines in order to enhance their profitability. The solution proposed in the Japanese study is to develop the manufacturing capability for responding to rapidly evolving and fragmented consumer markets.

Strikingly similar ideas are expressed in the American study conducted at the Iacocca Institute at Lehigh University (Dove & Nagel, 1991). "Agility" in manufacturing is defined, at least in part, as rapid response to new market opportunities. In identifying new markets, software systems are visualized which allow potential customers to simulate the use of virtual products and to cycle responses back into the product design. When new product concepts surface, a dynamic combination of corporations is mobilized to fill the need. Electronic communications among manufacturers and suppliers are required to realize this vision, and access to information must be improved by standardization and integration of existing heterogeneous (e.g., CAD/CAM) systems.

While critical time-to-market directives are addressed by distributed (virtual) enterprise systems, the design of products must go beyond concurrent engineering practices to incorporate product life cycle information. Highly modular component parts provide a sophisticated plug-compatible, mix-and-match approach to product construction. Improved parts or modules can then be integrated within existing products to provide almost continuous upgradeability. In this way, companies strive to develop long-term relationships with their customers as the product evolves to fit contemporary needs and technology.

One major difference between the American and Japanese studies appears to be in the conceptualization of a production system capable of manufacturing these diverse products. The American study relies on information management structures to utilize a diverse supplier network in matching product with manufacturing process. The Japanese study focuses on the modular design of an entirely new factory system, including machines and computer integrated manufacturing (CIM) software. Similar to the product modularity concept, the autonomous elements of the future factory can be easily removed, replaced and upgraded. In addition, overlapping functionality and information is proposed in order to increase the fault tolerant behavior.

Governments are not immune to the economic impact of these studies. A major international effort in intelligent manufacturing systems (IMS) is currently underway, as initiated by the Japanese. In addition, extensive research and development efforts are also beginning in the U.S. (Advanced Research Projects Agency, Department of Defense, National Science Foundation, etc.). These funding efforts encourage consortia development and multi-disciplinary brainstorming. While some anti-trust barriers have been relaxed in the U.S. with the enactment of the National Cooperative Research Act (NCRA) of 1984, the boundaries between research and commercialization and the ownership of intellectual property are still significant concerns.

This latest step in the evolution of production systems can be viewed in an historical context. While the economies of Europe and Asia were still recovering from World War II, U.S. factories tried to maximize throughput and machine utilization, recognizing that everything produced would be sold. As worldwide competition for consumer dollars increased, the inventory reduction, quality improvement and on-time delivery associated with the Japanese *kaizen* concept provided a leading edge. While satisfying customers through price, delivery and quality is an old idea, the current paradigm shift can be characterized by a new emphasis on technical systems for manufacturing customized products.

Industrial potential is indeed capable of rapid and profound transformations. The industrialization of East Asia represents an object lesson: in 1965, Singapore had virtually no industrial base. The implications for the IEEE Robotics and Automation Society membership are also clear. As a professional society, our engagement with the critical issues in manufacturing systems has the potential to facilitate the transitions in machine design, CIM systems, and product development. An important barometer for measuring the function and role of our Society lies in the contribution of our work to society at large.[1]

References

Dove, Rick and Roger Nagel (principal investigators), 21st Century Manufacturing Strategy, Bethlehem, PA: Iacocca Institute, Lehigh University, 1991.

Suda, Hiroharu, "Future Factory System Formulated in Japan," Parts 1 and 2, Techno Japan: Part 1, Vol. 22, No. 10, October 1989; Vol. 23, No. 3, March 1990.

1. A workshop at the 1994 San Diego Robotics and Automation Conference, exploring the implications of the manufacturing paradigm shift for society membership, is in an organizational phase.

Dan Whitney: From Robots to Design (from p.)

and permits designers to think about assembly in the small and assembly in the large at the same time.

Product design could begin with a rough layout that specifies approximate relations between parts and specifies how they will be joined. The joining relations could be specified by using library assembly features such as bearings and bearing seats, for example. It is possible to foresee setting up functional simulations by combining the inertia properties of the parts and their assembly relations, all of which would be captured when the parts were "assembled" by the designer.

Summary

In summary, I would like to reemphasize my original points. Robotics needs automation in order to remain vital and to have a reality check on its research directions. By looking at assembly, for example, researchers can formulate a wide variety of challenging problems that are often direct extensions of problems currently under study in robotics. If robotics researchers understand the constraints of the robot's environment, they can develop more robust methods and theories. If they do not, robotics applications will continue to be developed by industry, and robotics research will become inwardly directed and irrelevant. Second, automation needs robotics. There are many problems in assembly, for example, that will require robotics and computer science methods, such as 4x4 coordinate transformations, combinatorial planning, and database methods. If these and similar advanced methods are not applied, robot applications and progress will be limited to what can be achieved by the techniques of traditional engineering acting alone. Let's live up to the name of the Society: Robotics AND Automation.