2005 IEEE/ASME International Conference on Advanced Intelligent Mechatronics

AIM 2005

24—28 July 2005
Monterey, California
U. S. A.

PROGRAM

http://www.aim2005.org

Co-sponsored by
IEEE Industrial Electronics Society
IEEE Robotics and Automation Society
ASME Dynamic Systems and Control Division

WELCOME

On behalf of the organizing committee of AIM2005, I would like to welcome you to the 2005 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM2005). This is the fifth AIM conference following the previous ones held in Tokyo, Japan (1997), Atlanta, USA (1999), Como, Italy (2001) and Kobe, Japan (2003). The purpose of this biennial conference is to promote activities in various areas of mechatronics by providing a forum in exchange of ideas, presentations of technical achievement, and discussions of future directions.

The word *mechatronic*s represents the synergistic integration of precision mechanical engineering with advanced electronics and computer technologies in the design and manufacture of intelligent products and processes. Since the basic concept of mechatronics is quite general, it has found a wide variety of applications and systems ranging from automation, biomedical, automotive, data-storage devices, energy, home appliances, intelligent highways, manufacturing, robotics, and aerospace. Past successes have taken the AIM to a new height; the theme of this conference is "Intelligent Mechatronics in Micro/Nano Technologies". Micro and nano technologies will allow us to build devices enormously smaller than before and will bring fundamental changes to disciplines within engineering, chemistry, medicine, biology, and physics. The research on intelligent mechatronics is tremendously important to the development of micro and nano technologies, because most physical magnitudes characterizing micro and nano scale systems significantly differ from those familiar in macro and meso systems. It requires us to look the problem from different perspectives and provide new solutions. I hope the AIM2005 will provide an important platform and forum to further enable the development of intelligent mechatronics for micro and nano technologies.

The city of Monterey has been known as the perfect combination of land, sea and sky and is recognized as an ideal vacation and business destination. This beautiful seaside community combines all the charm of small town America with an endless variety of recreational and cultural activities. Monterey's rich history, the saga of California's Mission Trail, historic Fisherman's Wharf and Cannery Row, 17 world-class golf courses, one of the world's best aquarium, a unique variety of shops and galleries and a spectacular assortment of parks and natural areas combine to provide a truly unrivaled place. I hope you and your family will enjoy your stay in Monterey.

Finally, I would like to express my sincere thanks to the members of the organizing committee! Whatever you will enjoy in the conference is the result of their tireless effort.

Once again, I hope you and your family will have a wonderful time and enjoy both the technical and social programs of the AIM2005!

Ning Xi
General Chair

ABOUT THE PROGRAM

On behalf of the Institute of Electrical and Electronics Engineers (IEEE) and the American Society of Mechanical Engineers (ASME), I am glad to welcome you to the 2005 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2005). The purpose of this biennial conference, following the footsteps of the previous four editions in Tokyo, Japan (1997), Atlanta, USA (1999), Como, Italy (2001) and Port Island, Japan (2003), is to promote activities in various areas of mechatronics by providing a forum for exchange of ideas, presentation of technical achievements, and discussion of future directions. The conference returns to the USA for the second time. Past successes have taken the AIM to a new height; the theme of this conference is—*Intelligent Mechatronics in Micro/Nano Technologies.*

This year, a record number of 350 papers have been submitted from 32 different countries with an overall breakdown for the three greater geographical areas of about: 36% for America, 46% for Asia and Oceania, and 18% for Europe. These submissions include 34 invited session papers and 20 industrial oriented papers. For the first time, AIM2005 integrates paper submission/review, program production, and author registration in a single system, along with providing the authors a link to the free PDF conversion service tool offered by IEEE to convert the final manuscript into compatible PDF file to meet the new IEEE PDF compliance. Additionally, we require at least one author for each paper to register before uploading the paper; every attempt has been made to eliminate no-show at the conference. The review process has been conducted by the Program Chair, the four Program Co-Chairs and the Invited Session Chair. The process has been aided by the requirement that all papers be submitted in electronic form through PaperPlaze, thereby allowing each contribution to receive 3 independent reviews! Besides thanking all the Chairs for their prompt and efficient handling of the submission and review process, I take this opportunity to acknowledge the tremendous effort invested by the committee members for their reviewers of the papers. To promote submission of high quality papers and reviews, AIM2005 will present the best student paper awards to five finalists and review appreciation awards to three outstanding reviewers.

The technical program includes the presentation of 273 papers organized into 60 sessions in 5 parallel tracks. The Proceedings are provided in CD-ROM version, thanks to the work of the Publication Chair. In addition, the Final Program contains the 100-word abstracts of the papers which have been made available on the web http://www.aim2005.org prior to the Conference as well, thanks to the timely update of the web pages by the Publicity Chair. The Technical Program begins on Sunday (July 24) with 1 full-day and 4 half-day Tutorials promoted by the devoted Tutorial Chair. We are grateful to have three distinguished speakers: Christoph Gerber, Steven J. Madore and Hiroshi Shimizu offering plenary lectures on nano/micro-mechatronics and beautiful examples of mechatronics on biomedical, energy and environment. Paper Sessions are held in five parallel tracks from Monday to Wednesday covering a broad spectrum of topics and emerging areas addressing classical subjects such as modeling, sensor, design and control, up to fascinating mechatronic applications in micro/nano devices and manipulation, novel actuators, opto-mechatronics and color machine vision, data storage, bio-medical, automotive technology, and walking machines. The collection of papers includes original work on abstractions, algorithms, theories, methodologies, and case studies in the area of mechatronics. The highlights of the Social Program include a welcome reception on Sunday, a Monterey Bay Aquarium tour on Monday, and the conference banquet on Tuesday. A panel discussion, led by a group of distinguished advisory members, will be held following the conclusion of the technical sessions on Wednesday. Finally, Thursday (July 28) is dedicated to visit local industries, thanks to the dedication of the Industrial Tour Chairs.

A special word of appreciation goes to the General Co-Chair for his local arrangement effort and his tireless support to the organization of the event. We also thank the National Science Foundation for offering partial travel supports to student authors from the U.S.A. - thanks to the effort of the Invited Chair. Of course, we must remember and express our greatest recognition to all the Authors. Without their valuable contributions, there would be no conference at all.

On behalf of the AIM2005 team, we welcome you to participate in the AIM2005 Program. It is my great pleasure to meet you in Monterey!

Kok-Meng Lee
Program Chair

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Co-sponsored by

IEEE Industrial Electronics Society (IES)
IEEE Robotics and Automation Society (RAS)
ASME Dynamic Systems and Control Division (DSCD)

In cooperation with

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ACCOMODATION & CONFERENCE VENUE

Hyatt Regency Monterey: 1 Old Golf Course Road, Monterey, CA 93940-4908 USA

TRAVEL

Hyatt Regency Monterey is about three miles from the Monterey Airport. San Jose International Airport is 75 miles north of Monterey. San Francisco International Airport is 110 miles north of Monterey.

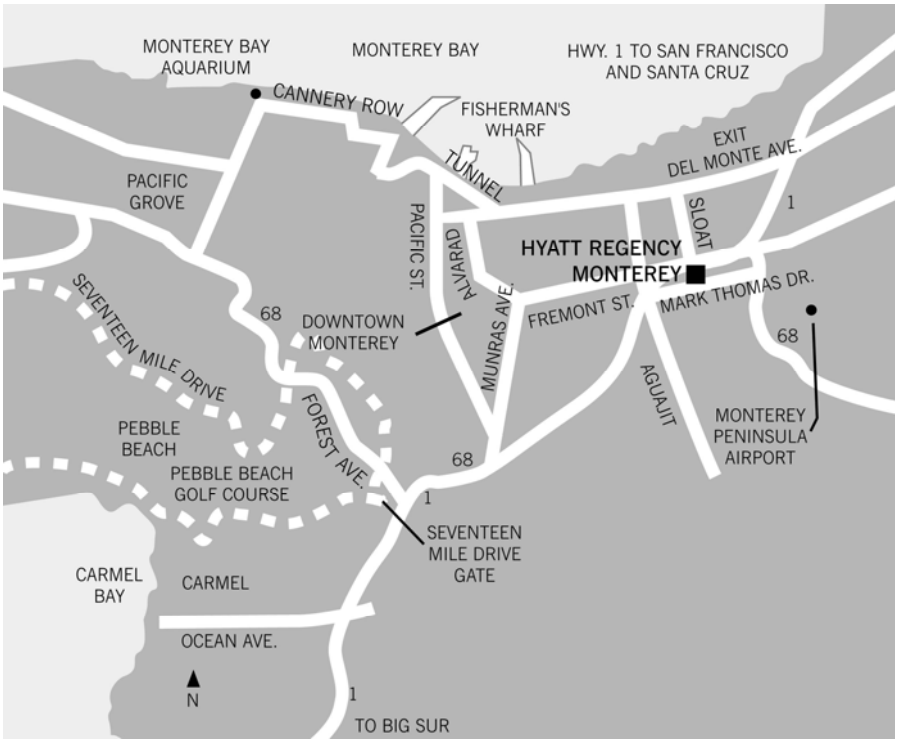
From Monterey Airport (MRY): It is only three miles from Monterey Airport to Hyatt Regency Monterey**.** The easiest way to get to Hyatt Regency is to take a taxi (about $6). If you choose to rent a car and drive to the Hyatt Regency, make a right turn to Garden Road as you exit the airport. Make a left turn at Fairground Road/Mark Thomas Drive. Then Turn left onto Old Golf Course Road.

From San Francisco International Airport (SFO): You may take a shuttle to Monterey, or rent a car and drive to Monterey. Airport shuttle service from San Francisco Airport and San Jose Airport is provided by *Monterey Salinas Airbus*.

Drive instructions from SFO to Monterey: Take South US-101 (90 miles). Then take West HWY- 156 (7 miles). West HWY-156 merges to South HWY- 1 (15 miles). After entering the Monterey City Limit, take the Del Monte/Pacific Grove exit. The exit ramp merges to Del Monte towards Pacific Grove. Turn left on Sloat AVE. Old Golf Course Road is at the end of Sloat AVE.

From San Jose International Airport (SJC): See SFO above for airport shuttle information.

Drive instructions from SJC to Monterey: Take South US-101 (50 miles). Then take West HWY-156 (7 miles). West HWY-156 merges to South HWY-1 (15 miles). After entering the Monterey City Limit, take the Del Monte/Pacific Grove exit. The exit ramp merges to Del Monte towards Pacific Grove. Turn left on Sloat AVE. Old Golf Course Road is at the end of Sloat AVE.



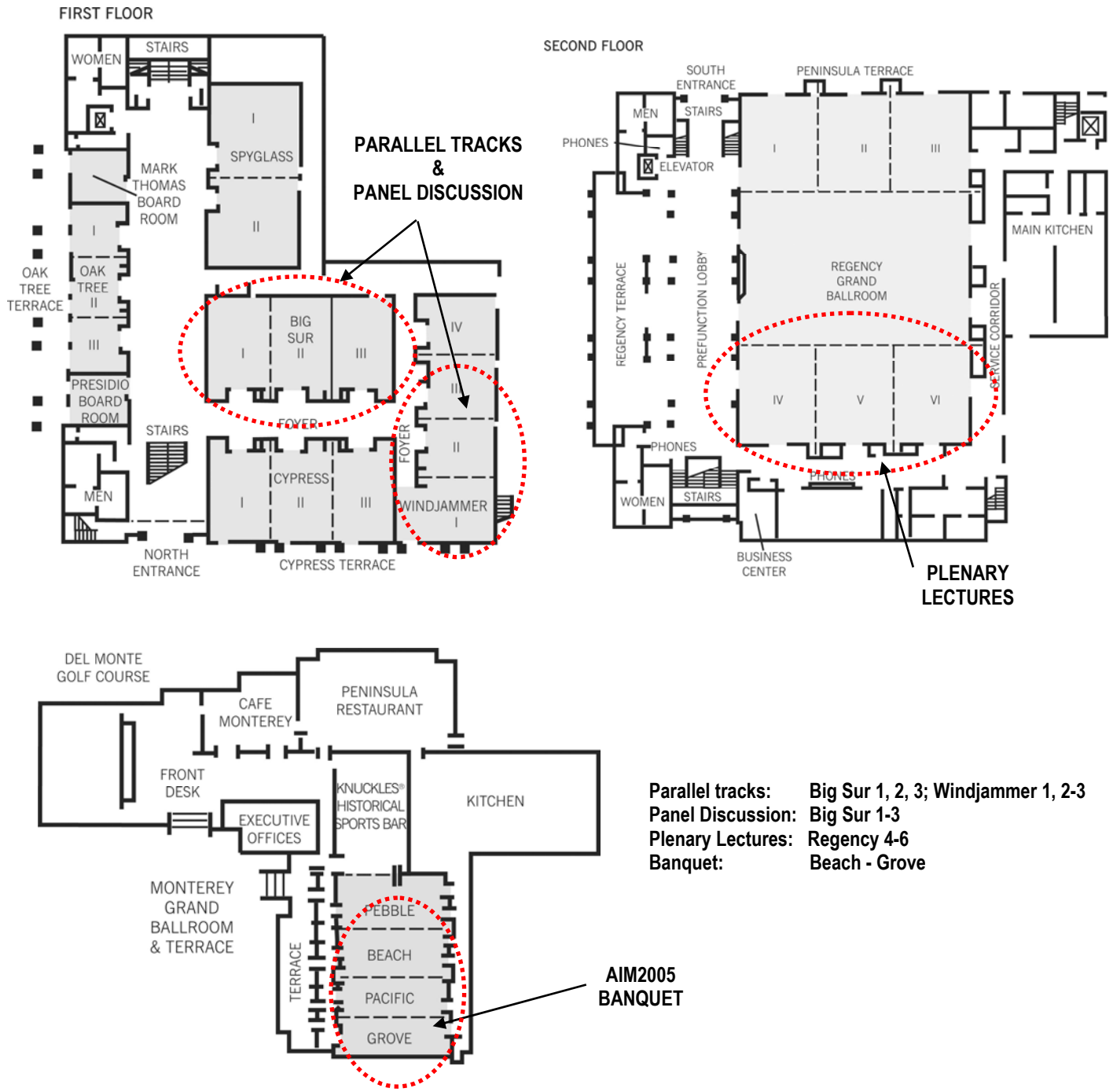
MONTEREY SALINAS AIRBUS SCHEDULE --- Reservation: (831) 373-7777 (http://www.montereyairbus.com/)

Depart Monterey	Depart Salinas/ Prunedale	Arrive SJC*	Arrive SFO	Depart SFO	Depart SJC	Arrive Salinas/ Prunedale	Arrive Monterey
4:00am	4:30am	5:30am	6:15am	6:45am	7:30am	8:30am	9:00am
5:30am	6:00am	7:00am	7:45am	8:15am	9:00am	10:00am	10:30am
7:00am	7:30am	8:30am	9:15am	9:45am	10:30am	11:30am	12:00pm
8:30am	9:00am	10:00am	10:45am	11:15am	12:00pm	1:00pm	1:30pm
10:00am	10:30am	11:30am	12:15pm	12:45pm	1:30pm	2:30pm	3:00pm
11:30am	12:00pm	1:00pm	1:45pm	2:15pm	3:00pm	4:00pm	4:30pm
1:00pm	1:30pm	2:30pm	3:15pm	3:45pm	4:30pm	5:30pm	6:00pm
2:30pm	3:00pm	4:00pm	4:45pm	5:15pm	6:00pm	7:00pm	7:30pm
4:00pm	4:30pm	5:30pm	6:15pm	6:45pm	7:30pm	8:30pm	9:00pm
5:30pm	6:00pm	7:00pm	7:45pm	8:15pm	9:00pm	10:00pm	10:30pm
7:00pm	7:30pm	8:30pm	9:15pm	10:00pm	10:45pm	11:45pm	12:15am

REGISTRATION

The registration desk will be located in the first floor lobby of the Hyatt conference center, **right next to the meeting room Big Sur I**.
Registration hours: 9:00am-5:00pm on Sunday, July 24, 2005
7:30am-5:00pm on Monday, July 25, 2005
8:00am-5:00pm on Tuesday, July 26, 2005
8:00am-12:00noon on Wednesday, July 27, 2005

HOTEL FLOOR PLAN



Parallel tracks: Big Sur 1, 2, 3; Windjammer 1, 2-3
Panel Discussion: Big Sur 1-3
Plenary Lectures: Regency 4-6
Banquet: Beach - Grove

PROGRAM LAYOUT

Sunday, July 24, 2005

09:00—12:00	~~T1: Modeling and Control of Automotive Fuel Cell Systems~~	T2: Micro- and Nanoscale Robotics	~~T4: Design of Remotely Operated Vehicle & Manipulator~~
14:00—17:00		T3: Network-Based Control Systems: A Tutorial	~~T5: Slip Sensors and "Intelligent" Robot~~
18:00—20:00	*Welcome Reception (Spyglass Promenade)*		

Monday, July 25, 2005

08:00—08:10	*Opening (Regency 4-6)*				
08:10—09:15	*Plenary 1 "Nanomechatronics: A Toolbox for the Small," Christoph Gerber (Regency 4-6)*				
	Track 1 (Big Sur 1)	*Track 2 (Big Sur 2)*	*Track 3 (Big Sur 3)*	*Track 4 (Windjammer 1)*	*Track 5 (Windjammer 2-3)*
MA 09:30—10:42	Data Storage Systems	Biomechatronics	Polymer Actuators	Opto-Mechatronic Sensors	Nanoscale Manipulation, Assembly and Synthesis
10:42—11:00	*Coffee Break*				
MB 11:00—12:30	Automotive Systems	Human-Machine Interfaces I	Precision Piezoelectric Actuators	Advanced Machine Vision Applications I	Micro and Nano Systems Design and Modeling
	Lunch Break				
MC 14:00—15:30	Vehicle Control	Human-Machine Interfaces II	Precision Electromagnetic Actuators	Advanced Machine Vision Applications II	Micro Manipulation and Assembly
15:30—15:45	*Coffee Break*				
MD 15:45—17:15	Locomotion	Human-Centered Robotics Systems	Actuators in Mechatronic Systems	Localization and Planning	Micro Robotics, Assembly and Synthesis
19:00—22:00	*Monterey Bay Aquarium Tour*				

Tuesday, July 26, 2005

08:00—09:15	*Plenary 2 " DNA Microarrays in Drug Discovery and Development," Steven J. Madore (Regency 4-6)*				
	Track 1 (Big Sur 1)	*Track 2 (Big Sur 2)*	*Track 3 (Big Sur 3)*	*Track 4 (Windjammer 1)*	*Track 5 (Windjammer 2-3)*
TA 09:30—10:42	Mechatronics in Medical Applications	Modeling and Design of Mechatronic Systems	Design of Parallel Mechanisms I	Sensor System Integration	Neural Control in Mechatronics
10:42—11:00	*Coffee Break*				
TB 11:00—12:30	Aerial and Underwater Robots	Dynamic Modeling of Robotic Manipulators	Design of Parallel Mechanisms II	Identification and Estimation in Mechatronics	Fuzzy Control Applications
	Lunch Break				
TC 14:00—15:30	Space Applications I	Fixture and Grasping	Design Optimization in Mechatronics	Sensors and Sensing Systems	Learning Control in Mechatronics
15:30—15:45	*Coffee Break*				
TD 15:45—17:15	Space Applications II	Flexible Manipulators and Structures	Computational Models and Methods	Magnetic Bearings	Mechatronics in Manufacturing Processes
19:00—22:00	*Banquet (Beach-Grove Room)*				

Wednesday, July 27, 2005

08:00—09:15	*Plenary 3 " Development of a High Performance Electric Vehicle: Eliica Hiroshi Shimizu (Regency 4-6)*				
	Track 1 (Big Sur 1)	*Track 2 (Big Sur 2)*	*Track 3 (Big Sur 3)*	*Track 4 (Windjammer 1)*	*Track 5 (Windjammer 2-3)*
WA 09:30—10:42	Multi-Robot System	Rehabilitation Robots	Artificial Intelligence in Mechatronics	Neuro-Fuzzy Control in Mechatronics	Motion Control
10:42—11:00	*Coffee Break*				
WB 11:00—12:30	Mobile Robot Systems	Tele-Operation	Software for Mechatronic Systems	Control Applications in Mechatronics I	Intelligent Process Automation
	Lunch Break				
WC 14:00—15:12	Network-Based Mechatronics	Visual Servoing	Sensor Platforms Enabling Multiple Modes of Mobility I	Control Applications in Mechatronics II	Robot Control
15:12—15:30	*Coffee Break*				
WD 15:30—16:42	Navigation of Mobile Robots	Industrial Vision	Sensor Platforms Enabling Multiple Modes of Mobility II	Vibration and Noise Control	Adaptive Control
17:00—18:30	*Panel Discussion and Closing (Big Sur 1-2-3)*				
18:30—20:00	*Farewell Reception (Regency 1-3)*				

Thursday, July 28, 2005

06:30—19:30	*Industry Tours* KLA Tencor (Milpitas, CA), Applied Materials (Santa Clara, CA), NASA Ames (Moffett Field, CA), and Research Labs at Stanford University

SOCIAL PROGRAM

Sunday, July 24, 2005

18:00 – 20:00
Welcome Reception @ Spyglass Promenade

All participants and guests are welcomed.

Monday, July 25, 2005

19:00 – 22:00
Monterey Bay Aquarium Tour

The ticket is required for the tour. Dinner and coffee/tea will be provided at the aquarium. Wine, beer and other drunks can be purchased. **We will meet and take the chartered buses outside the South Entrance (second floor entrance) of the Hyatt Conference Center at 5:30pm.** After arrival, you may first take a brief walk at the historic Cannery Row in the vicinity of the aquarium. **The AIM2005 group admission to the aquarium starts at 7:00pm through the member/group entrance located at an alley called Hovden Way, which is about 50 meters to the right of the aquarium main entrance.** The buses will be waiting outside the aquarium to take the group back to Hyatt hotel from 10:00pm. The last bus will leave at 10:30pm.

Tuesday, July 26, 2005

19:00 – 22:00
Conference Banquet @ Hyatt Regency Beach-Grove Room

For people with banquet tickets.

Wednesday, July 27, 2005

18:30 – 20:00
Farewell Reception @ Regency 1-3

All participants and guests are welcomed.

TECHNICAL PROGRAM

Sunday, July 24, 2005

09:00 – 12: 00 & 14:00 – 17: 00
Tutorials @ Big Sur 1

Monday, July 25, 2005

08:00 – 09:15
Plenary Lecture 1 (PL1) @ Regency 4-6

09:30 – 12:30 & 14:00 – 17:15
Paper Sessions (MA to MD in 5 parallel tracks)

Tuesday, July 26, 2005

08:00 – 09:15
Plenary Lecture 2 (PL2) @ Regency 4-6

09:30 – 12:30 & 14:00 – 17:15
Paper Sessions (TA to TD in 5 parallel tracks)

Wednesday, July 27, 2005

08:00 – 09:15
Plenary Lecture 3 (PL3) @ Regency 4-6

09:30 – 12:30 & 14:00 – 16:42
Paper Sessions (WA to WD in 5 parallel tracks)

17:00 – 18:30
Panel Discussion and Closing @ Big Sur 1-2-3

Thursday, July 28, 2005

06:30 – 19:30
Industry Tours

TUTORIALS

Sunday, July 24, 2005

T1	**Tutorial 1**
	~~09:00 – 12:00, 13:00 – 16:30~~ (Cancelled)
	ORGANIZER: Huei Peng, USA

Modeling and Control of Automotive Fuel Cell Systems

Huei Peng, **Ph.D.**
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Ann Arbor, MI 48109, USA

Starting from the 1990's, the continuous pursuit of high-efficiency power train for ground vehicles has resulted in significant interest in two new classes of vehicles: vehicles with hybrid power train and vehicles that use fuel cell as the prime mover. Currently, most major car companies have active programs for both hybrid electric vehicles and fuel cell vehicles, some with very aggressive production plans using the former technique. Most researchers, however, agree that hybrid vehicles are a short- to mid-term solution. In the long run, techniques for sustainable mobility have to be developed, which rely on renewable energy sources to power ground transportation devices.

The fuel cells are widely perceived as the enabling technology toward the future conversion toward renewable power trains. Currently, there are still many important bottlenecks that need to be addressed, including membrane, manufacturing, reliability and overall cost reduction. The focus of our research at the University of Michigan has been on the modeling and control side, with special focus on the control of breathing, membrane humidity and their effect on power generation. The fuel cell system model we developed has been distributed and used widely, and we would like to cover the basic ideas behind fuel cell system and fuel cell vehicle modeling and control, with a couple of recent examples developed at the University of Michigan. Our experience on the design of a military truck with fuel cell Auxiliary Power Unit (APU) will also be briefly reported. The workshop will conclude with a demonstration of the fuel cell vehicle simulation program (FC-VESIM) written in SIMULINK.

Outline:

9.00–9:50:
- Overview of tutorial
- Background and introduction
- Energy and needs of alternative power sources

10:00–10:50
- Automotive Industry Perspective and Needs
- Academic Perspective--Research needs

11:00–12:00
- Fuel Cell Stack System--fundamental and modeling

1:00–1:50
- Modeling of the Balance of the plant
- Fuel Cell Vehicle models

2:00–2:50
- Control of fuel cell vehicles and hybrid vehicles

3:00–3:50
- Examples of SIMULINK models--FC-VESIM

4:00–4:30
- Q and A and wrap-up

Sunday, July 24, 2005

T2	Tutorial 2 Big Sur 1 (09:00 – 12:00)		Tutorial 3 Big Sur 1 (14:00 – 17:00)	T3
	Metin Sitti, USA	**ORGANIZER**	**Mo-Yuen Chow, USA**	

Micro- and Nanoscale Robotics

Metin Sitti, **Ph.D,** *sitti@cmu.edu*
NanoRobotics Laboratory
Department of Mechanical Engineering and Robotics Institute
Carnegie Mellon University, Pittsburgh, PA 15213, USA

For the miniaturization of devices and machines down to atomic and molecular sizes, micro/nanorobotic approach enabling precision manipulation, manufacturing, and interaction at the micro- and nanoscales is indispensable. Micro/Nanorobotics as an emerging field is based on the micro/nanoscale physics, fabrication, sensing, actuation, system integration, and control taking the scaling effects into consideration. Micro/Nanorobotics encompasses: (i) design and fabrication of micro/nanorobots with overall dimensions at the millimeter and micrometer ranges and made of micro/nanoscopic components; (ii) programming and coordination of large numbers of micro/nanorobots; and (iii) programmable assembly of micro/nanoscale components. This tutorial will focus on state-of-the-art micro/nanorobotics research topics, challenges, and activities around the world and at the NanoRobotics Laboratory.

As the first focus area, precision nanomanipulation systems using Atomic Force Microscope (AFM) probes will be introduced. Here, AFM probes are utilized as a pushing, pulling, cutting, and indenting type of nanomanipulator, and also as a three-dimensional (3-D) topography and force sensor. As the first application, using an AFM probe and a teleoperated human-machine interface, fine gold particles down to 14nm radius are positioned in two-dimension by mechanical pushing for developing micro/nanoassembly technology, and teleoperated touch feedback from the surfaces at the nanoscale is realized. Next, liquid polymers are pulled and solidified precisely by an AFM probe to manufacture customized 3-D polymer micro/nanofibers. Next, design methodology, analysis, and fabrication of biomimetic fibrillar adhesives inspired by geckos are explained. Geckos have unique dry adhesive fibers in their feet to climb any surface with a very high maneuverability. Discovering the principles of gecko adhesion recently, synthetic polymer micro/nanofibers are fabricated using micro/nanomolding techniques. The results of current prototype adhesive fibers and miniature climbing robots inspired by geckos are reported. Finally, miniaturization issues of micro/nanorobots are discussed. As current miniature robotics activities, biomedical swimming and endoscopic capsule microrobots, water strider robots walking on water, and Integrated Nano-Tool Carrier walking robots are explained briefly, and challenging issues are addressed. These miniature robots could revolutionize health-care, environmental monitoring, manufacturing, and space exploration applications in the future.

Outline:

1. Introduction
   - Background on Micro/Nanorobots
   - Scaling Effects and Micro/Nanophysics
   - Sensors, Actuators, Manipulators, Control
   - Micro/Nanorobot examples around the world
2. Micro/Nanomanipulation with an Atomic Force Microscope (AFM)
   - Background
   - The AFM as a Robot
   - Manipulation Examples and Applications
3. Miniature Microrobots
   - Climbing robots inspired by geckos
   - Biomedical swimming and endoscopic capsule microrobots
   - Water strider robots walking on water
   - Integrated Nano-Tool Carrier precision walking robots
   - Challenges and Applications
4. Summary and Outlook

Network-Based Control Systems: A Tutorial

Mo-Yuen Chow, **Ph.D,** *chow@ncsu.edu*
Department of Electrical and Computer Engineering
North Carolina State University
Raleigh, NC 27695-7911, USA

For many years now, data networking technologies have been widely applied in the control of industrial and military applications. These applications include manufacturing plants, automobiles, and aircrafts. Connecting the control system components in these applications, such as sensors, controllers, and actuators, via a network can effectively reduce the complexity of the systems with nominal economical investments. Furthermore, the applications connected through a network can be remotely controlled from a long-distance source. Traditionally, the networks used in the aforementioned applications are specific industrial networks, such as CAN (Controller Area Networks) and PROFIBUS. However, general data networks such as Ethernet/Internet are rapidly advancing to be the networks of choices for many applications due to their flexibility and lower costs.

A challenging problem in control of networked-based system is *network delay effects*. The time to read a sensor measurement and send a control signal to an actuator through the network depends on network characteristics such as their topologies, routing schemes, etc. Therefore, the overall performance of a network-based control system can be significantly affected by network delays. The severity of the delay problem is aggravated when data loss occurs during a transmission. Moreover, the delays do not only degrade the performance of a network-based control system, but also can destabilize the system.

This tutorial presents fundamental details of network-based control and recent network-based control techniques for handling the network delays. The techniques are based on various concepts such as state augmentation, queuing and probability theory, nonlinear control and perturbation theory, and scheduling. A general structure of a network-based control system, delay types, and delay behaviors are also described in this tutorial. In addition, advantages and disadvantages of these techniques are discussed. A new approach on using gain-scheduling middleware (GSM) to complete network-delay effect will also be introduced. A network-based control path-tracking problem will be used to illustrate the GSM technology.

Outline:

1. Overview of network-based control system (or networked control system).
   - Different types of networks for network-based control
   - Advantages of using a network as shared media in a control system
   - Network-based control system structures
   - Data transfers
   - Constraints and challenge in network-based control systems
2. Main concerns – network in the loop induced delay
   - Behaviors of Internet network delays
   - Modeling
   - Effects of network delays
3. Several network-based control approaches
   - Augmented deterministic discrete-time model method
   - Queuing method
   - Optimal stochastic control method
   - Perturbation method
   - Sampling time scheduling method
   - Robust control method
   - Smith predictor method
   - Fuzzy logic method
   - End-user control adaptation method
   - Fuzzy logic modulation method
   - Gain scheduling middleware
4. Illustration:
   - Mobile robot teleoperation for path tracking using gain scheduling middleware
5. Tutorial summarization and remarks

T4	Tutorial 4		Tutorial 5	T5
	~~09:00 – 12:00~~ (Cancelled)		~~14:00 – 17:00~~ (Cancelled)	
	Debanik Roy, India	**ORGANIZER**	**Debanik Roy, India**	

Design Of Remotely Operated Vehicle & Manipulator: Critical Issues & Realization

Debanik Roy, **Ph.D,** debanik@rediffmail.com
Scientist
Division of Remote Handling and Robotics
Bhabha Atomic Research Centre
Mumbai 400085, INDIA

This tutorial is aimed towards analyzing the design criticalities vis-à-vis building up a comprehensive application oriented design model for a small-sized tethered ROV system, having sufficient dexterity as well as maneuverability in potentially hostile underwater environments.

Underwater vehicle dynamics may be as complex to model principally due to difficulties in observing and measuring actual underwater vehicle hydrodynamic response, as it is not constrained. The effects of forces and moments can all be cross-coupled between vertical, lateral and horizontal directions as very large angles of attack between vehicle orientation and vehicle direction of motion are possible. The effects of the surrounding environment are relatively large and significant, so much so that adjacent water tends to be accelerated along with the vehicle and may be modeled off as added mass. There are over 100 pertinent coefficients / variables related to the linear and non-linear coupled effects, e.g. lift, drag, added mass and propulsion effects, which do play a major role in a representative model. Coupled with these challenges the facets like physical response, guidance and control of a ROV become an extremely difficult dynamics problem. Although a number of these coefficients are of second-order effect or of negligible importance, determination of primary coefficient values is very difficult and expensive. These problems are frequently compounded as the vehicle generally has an open frame with irregular surfaces and towed tether attached.

Underwater vehicles often include free-flood spaces, which can be compared with ocean pressure through small openings, while remaining essentially contained by the hull. The water enclosed in these free-flood spaces directly contributes to both volumetric displacement and vehicle mass. Thus free-flood spaces affect buoyancy, mass, center of buoyancy, center of mass and vehicle hydrodynamic response. Besides, the drag due to tether is more relevant for deepwater systems wherein vehicle drag can be neglected as noise. The multi degrees of freedom hyper-redundant active manipulator is the most widely used attribute for most of the URV applications due to flexibility and dexterity in the operation. Generally the manipulator joints are of revolute type since it culminates in smoother drive control system and easy construction, while the end effectors may be custom made.

For passive manipulators, a Revolute-Revolute-Prismatic (RRP) type 3 d.o.f. design is one of the optimal choices. This 2 d.o.f R-joint is to be connected to a compact telescopic prismatic joint (fitted with vacuum suction pad) so that it can dock at any required length and orientation.

Outline:
Introduction to Underwater Robotics (10 min.)
Design aspects of ROV: Overview (20 min.)
Detailed design issues for ROV manipulators. (1 hour)
Detailed design issues for Underwater Vehicle Body (1 hour)
Design issues:
Sensor systems, Tether management, controller etc. (30 min.)

Slip Sensors and "Intelligent" Robot

Debanik Roy, **Ph.D,** debanik@rediffmail.com
Scientist
Division of Remote Handling and Robotics
Bhabha Atomic Research Centre
Mumbai 400085, INDIA

This tutorial is aimed at describing research issues and design creativities pertaining to slip sensors, as used in an instrumented robotic gripper supported by allied technical features.

Slip-resistant robust grasping of objects during remote manipulation remains one of the major *open* issues. Finer measurement of tangential force and slippage need to be considered for task planning and control of robotic gripper in *tele-operation*. Although numerical estimation and measurement of grasp force can be optimally sufficient for all practical purposes, however a much exhaustive analysis is required for the fine-tuning of such manipulation by a robotic gripper (because of slip). Different designs of *miniaturized slip sensors*, to be interfaced with the robotic gripper, have been researched out by the author. Those may be categorized as,

A: In the form of a multi-sensory tactile array:
Here *sensing members* follow a combination of beam (bending) and truss-type (axial deformation) behavior under external loadings. The novelty of the design dwells in the association of *quasi-truss* type feature, unlike the commonly found deformation through (beam) bending. The quasi-compliant tactile sensory system is composed of three types of elemental sensing units (*taxels*), namely: [a] resistive sensors [b] capacitive sensors [c] PVDF (Polyvinylidene Fluoride) sensors. Resistive and capacitive units are responsible for the detection of static forces while PVDF sensors are entrusted for arresting the responses due to dynamic loadings / micro-forces coming on the gripper surface. Here, slippage is modeled theoretically for three different situations, namely, [I] incipient slippage; [II] posteriori slip (micro level) & [III] macro-level slip. The sensor provides quantitative measures like slip velocity and distance slipped.

B: In the form of a planar segmented architecture:
In this design, each of the gripper jaw plate incorporates a *matched* set of *Thin-Beam Sensors*. The maximum deflection of these sensors is restricted through two *stoppers* per sensor. The assembly of the slip-sensing members is in contact with the rubber pad, atop the jaw. The thin-beam sensors are activated by the *excitations* generated through a set of vertically *projecting pins* (two pins for each sensor).

The research domain of intelligent robot grippers is finely intermixed with the grip & slip sensory systems. Detailed design & developmental analysis will be made on *three-finger gripper* (for tele-operation), *magnetic gripper* (for industrial use), *parallel-jaw mini-gripper* (for flexible manipulator), *miniaturized vacuum gripper* (for mobile robotic system) etc.

Compliant wrist is another important element is designing intelligent grippers. The author has developed various designs of miniaturized compliant wrist, having requisite compliance in axial & radial directions, which are particularly useful for small-sized flexible manipulators. These are: using (a) compression spring-elements (b) passive spring-elements (c) pneumatic spring-elements and (d) sensor-based spring-elements.

Outline:
Introduction to Force Nomenclature in Robotic Gripping (10 min.)
Design aspects of Slip Force sensing (20 min.)
Detailed design issues for Slip Force Sensor (1 hour)
Detailed design issues for Intelligent Gripper (1 hour)
Design issues on:Micro-actuation, MEMS, Micro-gripper & Flexible gripper (30min)

PL1	Plenary Lecture 1		Plenary Lecture 2	PL2
	Monday, July 25, 2005	**08:00—09:15**	**Tuesday, July 26, 2005**	
	Regency 4--6	ROOM	Regency 4--6	
	Kok-Meng Lee, Georgia Inst. of Tech	HOST	Stefano Chiaverini, University of Cassino	

Nanomechatronics: A Toolbox for the Small

Christoph Gerber, National Center of Competence for Nanoscience, and IBM Research Lab., Switzerland

The newest developments in dynamic force microscopy reveal unprecedented molecular resolution on insulating surfaces. Trapping molecules in nanometer-sized containers on a KBr(001) insulating surface shows for the first time that phthalocyanine-related polar molecules can be confined and studied on a individual bases . This offers fascinating perspective for novel electronic devices on the nanometerscale. A transition from stick -slip to continuous sliding is observed for atomically modulated friction by means of friction force microscopy resulting in a new regime of ultra low friction in a newly postulated concept "superlubricity". Micro-fabricated silicon cantilevers arrays offer a novel label-free approach where ligand-receptor binding interactions occurring on the sensor generate nanomechanical signals like bending or a change in mass that is optically detected in-situ. We report the detection of multiple unlabelled biomolecules simultaneously down to picomolar concentrations within minutes. Differential measurements including reference cantilevers on an array of eight sensors enables sequence-specifically detection of unlabelled DNA and is suitable to detect specific gene fragments within a complete genome (gene fishing). Expression of detection of inducible genes as well as the ultimate challenge: the detection of total RNA fragments in an unspecific back ground will be shown. Ligand-receptor binding interactions, such as antigen recognition will be presented. Antibody activated cantilevers with sFv (single chain fragments) which bind to the indicator proteins show a significant improved sensitivity which is comparable with SPR (Surface Plasmon Resonance). In addition this technology offers a brought variety of receptor molecules application such as e.g. membrane protein recognition, micro-organism detection, enantiomeric separation. New coating procedures, enlargement of the active surface area by dendritic molecules as well as improvement of the receptor-cantilever chemical bond will be presented. This new findings may lead to a novel individual diagnostic assay in a combined label-free GENOMICs and PROTEOMIC biomarker sensor (COMBIOSENS).

Christoph Gerber is the Director for scientific communication of the National Center of Competence for Nanoscale Science (NCCR) at the Institute of Physics, University of Basel, Switzerland and is a Research Staff Member emeritus in Nanoscale Science at the IBM Research Laboratory in Rüschlikon, Switzerland . During the past 25 years, his research was focused on Nanoscale Science. He is a pioneer in Scanning Probe Microscopy, and made major contributions to the invention of the Scanning Tunneling Microscope (STM) and the Atomic Force Microscope (AFM). He is also a co-inventor of Biochemical sensors based on AFM Technology. Prof. Dr. Gerber is the author and co-author of more than one hundred scientific papers that appeared in peer-reviewed journals with more than 12000 citations in cross disciplinary fields. He belongs to the worldwide one hundred most cited researchers in Physical Sciences. He gave numerous plenary and invited talks at international conferences. His work has been recognized with multiple honorary degrees. He is a fellow of the American Physical Society and a fellow of the IOP Institute of physics of UK .His IP portfolio contains 37 patents and patent publications. His current interests include Biochemical sensors based on AFM Technology, chemical surface identification on the nanometer scale with AFM, nanomechanics, nanorobotics, and molecular devices at the ultimate limits of measurement and fabrication, Atomic Force microscopy research on insulators, single spin magnetic resonance force microscopy (MRFM), combined scanning SQUID and AFM, self-organization and self-assembly at the nanometer scale.

DNA Microarrays in Drug Discovery and Development

Steven J. Madore, Pfizer, Inc., USA

Messenger RNA (mRNA), a single stranded nucleic acid, serves as the critical intermediary in the transfer of genetic information encoded in the DNA blueprint into a form that can be recognized by the protein synthesis apparatus of the cell. In general, mRNA levels are indicative of the type and amount of proteins made in a cell, and therefore serve as a surrogate indicator of cellular protein levels. Understanding which proteins have altered levels of expression in disease conditions can lead to the identification of novel drug targets. Current technology prohibits measuring the levels of all the proteins made in a cell; however, a high throughput hybridization methodology using DNA microarrays facilitates the quantification of mRNA levels in an overnight reaction. Microarrays consist of thousands of molecular probes arrayed onto a glass surface or nylon membrane support. Fluorescently tagged "target" prepared from cellular mRNA is applied to the surface of the array, and each target molecule, representing a unique mRNA in the total population, binds to its cognate DNA probe on the surface of the array. In general the intensity of the fluorescent signal from each probe is indicative of the levels of that specific mRNA in the original sample. Applications for microarrays in the drug discovery process include target identification, compound MOA analysis and toxicity evaluation, identification of genetic polymorphisms, and biomarker identification.

Steven J. Madore was born and raised about 40 miles west of Boston in Auburn, Massachusetts - the site of Dr. Robert Goddard's famous rocket launch. He received a B.S. in Microbiology from the University of Massachusetts, Amherst in 1984 and a PhD in 1991 in Cellular and Developmental Biology from the State University of New York at Stony Brook. Dr. Madore was a postdoctoral fellow in Dr. Bryan Cullen's laboratory at the Howard Hughes Medical Institute, Duke University Medical Center from 1991 to 1995 where he worked on the regulation of gene expression in HIV-1. He joined the faculty of the Dermatology Research Unit at the University of Michigan in Ann Arbor in 1995 where he studied the molecular mechanisms of skin photo damage. In 1998 he accepted a position in the Molecular Biology Department at Parke-Davis as leader of the Expression Profiling Group, a position he currently holds in the Pfizer Global Research and Development organization. He is a member of the American Society of Biochemistry and Molecular Biology and on the editorial review board of the Journal of Biological Chemistry. His scientific interests include genomics, eukaryotic transcriptional regulation and RNA processing. Steve is married to Jamie and has 12-year old triplets named Cameron, Mackenzie, and Madison. He enjoys golf, is a youth soccer and hockey coach, and is a USA Hockey registered ice hockey referee.

PL3	Plenary Lecture 3		Panel Discussion	PD
	08:00—09:15	Wednesday, July 27, 2005	17:00—18:30	
	Regency 4--6	ROOM	Big Sur 1-2-3	
	Masayoshi Tomizuka, UC - Berkeley	HOST	Toshio Fukuda, Masayoshi Tomizuka	

Development of a High Performance Electric Vehicle: Eliica
Hiroshi Shimizu, Keio University, Japan

When the world's gasoline gauge tips towards "empty" in the coming decades, we are going to have to use a lot of imagination and creativity to compensate. This, together with the needs to tackle current traffic issues such as air pollution, energy consumption, traffic accidents, and traffic jams, led us to find ways to improve today's automobiles. This includes the switch to electric vehicles, utilization of automatic drive systems, and the downsizing of these electric vehicles with automatic drives. At Keio University in Japan, a high performance electric vehicle named "Eliica" (Electric Lithium Ion Car), a five passenger sedan, was developed from the ground up; lithium-ion batteries, permanent-magnet motors and IGBT inverters are used as driving components. In-wheel motors are put in each eight wheels and all batteries and inverters are set in the frame structure under the floor. Eliica has a maximum velocity of 370km/h and can accelerate from 0 to 160 km/h in 7.0 seconds.

"Among concept cars, hybrid electric are still going strong, and more of them are being built with lithium-ion batteries rather than …. The wildest lithium-ion vehicle so far has to be the luxury-sedan concept *Eliica* from Keio University in Japan…" See "Top Tech Cars" *in IEEE Spectrum*, March 2005, page 22-30.

Hiroshi Shimizu, born in 1947, graduated from the Graduate school of Tohoku University in 1975 in Applied Physics. He joined the Ministry of Environment of the National Institute for Environmental Studies, Japan, as a Researcher in 1976. Since 1997, he is a Professor of Media and Governance in the Faculty of Environmental Information, Keio University.

Grand Challenges of Advanced Intelligent Mechatronics

Perspectives on future challenges of mechatronics
Toshio Fukuda (Host), Nagoya University, Japan
Wayne Book, Georgia Institute of Technology, U.S.
Roland Siegwart, Swiss Federal Institute of Technology, Switzerland

Research Funding Opportunities in U. S.
Masayoshi Tomizuka(Host), University of California, Berkeley
Mario Rotea, National Science Foundation
Yifan Chen, Ford Motor Company

INDUSTRIAL TOUR

Thursday, July 28, 2005

6:30: Leave Monterey bay conference site.

8:40-10:00: KLA-Tencor. KLA-Tencor is the world's leading supplier of process control and yield management solutions for the semiconductor and related microelectronics industries. Plan to visit the company's fabrication lines involved in-line wafer defect monitoring, CD SEM metrology, wafer overlay, film and surface measurement.

10:30-12:00: Applied Materials, Inc. Applied Materials is the world's largest supplier of products and services to the global semiconductor industry. Plan to visit the company's Maydan Process Module Technology Center, which has the latest semiconductor fabrication facility that includes wafer inspection, transport, and many other advanced automated systems and test equipment.

12:00 -13:30: Lunch.

13:30-15:00: NASA Ames Research Center. Will visit the Mars Center, which features interactive displays and exhibits focused on Mars, the Mars Exploration Rover mission and Ames' scientific and engineering roles in Mars missions - both past and present. Visit shows of software tools used by planetary scientists to determine the best and safest sites for the Mars Exploration Rover landings.

15:30-17:30: Stanford University. Visit the New Mechanical Engineering Research Lab, Micro-Transducers, Micro-Machining, Biomedical Engineering Lab, Micro-scale Mechanical Engineering Lab, Neuro-muscular Biomechanics Lab.

19:30 PM: Return to the conference site.

MA1	Data Storage Systems		Biomechatronics	MA2
	Big Sur 1 (09:30—10:42)		Big Sur 2 (09:30—10:42)	
	Lilong Cai, Hong Kong	CHAIR	Mingjun Zhang, USA	
	Tsu-Chin Tsao, USA	CO-CHAIR	Metin Sitti, USA	

09:30—09:48

Adaptive and Optimal Rejection of Non-Repeatable Disturbance in Hard Disk Drives

Y.-H. Kim, Samsung Electronics, *C.-I. Kang,* Cheju National U., Korea, *M. Tomizuka,* U. of California, USA

This paper presents an efficient control strategy to reduce the non-repeatable position error signal (PES) components caused by mechanical vibration in hard disk drives. A peak filter is designed that plugs into a servo loop in parallel with the existing controller. Based on the PES, the filter's center frequency is adaptively searched for in order to identify a dominant spectral peak. An analytical procedure is proposed to design the filter that minimally affects the stability of control systems and the distortion in the error rejection curve. The performance and practicality of the proposed strategy are demonstrated by simulation and experiment.

Integrating Molecular Dynamics for DNA Bio-Chip Fabrication and Hybridization Automation

M. Zhang, Agilent, *P. A. Pianetta,* Stanford U., *T. J. Tarn*, Washington U., USA

Integrating molecular dynamics for DNA bio-chip fabrication and hybridization automation is promising. The challenge is on obtaining dynamic models for micro-/nano-scale system controls. This paper concerns dynamics of single-stranded DNA molecules tethered to substrate surfaces. A nonlinear control model based on the dynamics model is proposed for DNA bio-chip fabrication and hybridization automation. The contributions of this paper consist of a nonlinear control model for single-stranded DNA molecules tethered to silica surfaces, and integration of the dynamics model for wafer-scale bio-chip fabrication and hybridization automation.

09:48—10:06

Short-Span Seeking of HDD by Vibration Suppression PTC Based on Controllable Canonical Realization

H. Fujimoto, K. Fukushima, Yokohama Nat. U., *S. Nakagawa,* Hitachi, Japan

In a short distance seeking-mode for hard disk drives, the resonance modes are getting crucial obstruction to meet the demand on high-speed date access. In this paper, a novel vibration suppression perfect tracking control (PTC) method is proposed based on a modified controllable canonical realization. In the proposed method, it is assumed that plant is modeled as the rigid and primary resonance modes. By using this model, a feedforward controller is designed with multirate PTC to control the transient response of position, velocity, acceleration, and jerk of the proposed virtual plant. Simulations and experiments are carried out to show that the proposed system can suppress the primary vibration mode in short-span seeking control.

Analysis of Utterance in Long-Term Robot Assisted Activity for Elderly People

K. Wada, T. Shibata, K. Sakamoto, T. Saito, K. Tanie, National Inst. of Advance Science and Tech. (AIST), Japan

A long-term experiment of robot assisted activity for elderly people has been conducted at a health service facility for the aged since Aug. 2003. Three therapeutic seal robots, Paro, were introduced there. This paper describes the results of the experiment for one year. Face scales that consist of illustrations of person's faces were used to evaluate person's moods. In addition, utterances of elderly to seal robots were analyzed quantitatively. As the results, numbers of the utterance of elderly people were increased, and their feelings were improved by interaction with the seal robots.

10:06—10:24

Robust Adaptive-Q with Two Period Repetitive Control for Disk Drive Track Following

K. Kalyanam, T.-C. Tsao, UCLA, USA

This paper presents the design and implementation of a robust adaptive and repetitive control for rejecting repeatable and nonrepeatable runout disturbance in the computer disk drive read-write head tracking following. An LQG controller is augmented by a plug-in repetitive control for rejective periodic disturbances and an adaptive-Q control to reject the remaining aperodic and random disturbances. The control system is shown to be robust stable under plant model uncertainty using small gain arguments. Experimental results of the control implementation on a 7200 rpm disk drive show substantial track following performance improvement of the two-layered augmented controller over the base line LQG control or the single layer repetitive or adaptive-Q control augmentation.

Modeling and Testing of a Biomimetic Flagellar Propulsion Method for Microscale Biomedical Swimming Robots

B. Behkam, M. Sitti, Carnegie Mellon Univ., USA

Medical applications are among the most impactful areas of microrobotics. Miniature, safe and energy efficient propulsion systems hold the key to maturing the medical microrobotics technology but they pose significant challenges. Authors propose a new type of propulsion inspired by the motility mechanism of prokaryotic microorganisms. The performance of this propulsive mechanism is estimated by modeling the dynamics of the motion. Analyzing key parameters such as linear velocity and efficiency, the optimum design of propulsion mechanism for miniature robots is demonstrated. In order to validate the theoretical result for flagella propulsion, a scaled up prototype of the swimming robot is fabricated and characterized in silicone oil using the Buckingham PI theorem for scaling.

10:24—10:42

Design, Fabrication and Control of a Micro X-Y Stage with Large Ultra-Thin Film Recoding Media Platform

Y. Lu, C. K. Pang, J. Chen, H. Zhu, J. P. Yang, J. Q. Mou, G. X. Guo, Data Storage Inst., *B. M. Chen, T. H. Lee,* National U. of Singapore, Singapore

We report a design of the micro X-Y stage with 6 mm x 6 mm recording media platform, which is actuated by comb-drives. The fabrication process including the integration of the 40 nm thickness PMMA (polymethyl methacrylate) recording media is presented. The prototype of the micro X-Y stage is fabricated by micromachining techniques. The FEA (finite element analysis) results show that the first two modes of the X-Y stage are in plane modes at 440 Hz. The displacement of the media platform can achieve 20 um with the driving voltage of 55 V. A control scheme is designed and simulated. It shows that the closed-loop system has strong error and vibration rejection capabilities.

Motion Control of Euglena Group by Weak Laser Scanning System and Object Manipulation Using Euglena Group

A. Itoh, W. Tamura, T. Mishima, Tokyo Denki Univ., Japan

This study investigates how to use protozoa as huge group of living micromachines. Motion control of protozoa is made by using the orientation phototaxis of Euglena. Blue laser scanning system is made for motion control. Construction is that blue laser passed through two galvano-scanners to make the two dimensional positioning, concentrated by a convex lens, and irradiated into the experimental pool. Blue light is attenuated by high cut filter, and recorded by CCD camera with macro lens. Red LED light is used for background illumination. Experimental results show that this system can make any shape of Euglena group by gathering along the scanned laser beam. It can also control the motion of Euglena group, and we can move objects by using this Euglena group as a micro manipulation system.

MA3	Polymer Actuators		Opto-Mechatronic Sensors	MA4
	Big Sur 3 (09:30—10:42)		Windjammer 1 (09:30—10:42)	
	Wen J. Li, Hong Kong	CHAIR	Wei Wei Wang, Canada	
	Masaki Yamakita, Japan	CO-CHAIR	Li-Chen Fu, Taiwan	

09:30—09:48

Control of Biped Walking Robot with IPMC Linear Actuator

M. Yamakita, N. Kamamichi, T. Kozuki, Tokyo Inst. of Tech.,
K. Asaka, National Inst. of Advanced Industrial Science & Tech. (AIST),
Z.-W. Luo, Inst. of Physical & Chemical Res. (RIKEN), Japan

We developed an artificial muscle linear actuator using ionic polymer-metal composite (IPMC) which is an electro-active polymer (EAP) that bends in response to electric stimuli. In this paper, we consider control of a small-sized biped walking robot. It is shown throughout the simulations the biped robot with IPMC linear actuators can walk by a simple input synchronization to motion of the robot and a feedback control. We also investigate a re-doping effect that is change of the characteristics by ionic re-doping chemically. Furthermore, a preliminary walking experiment is conducted.

Bidirectional Motion Detection Using Protein-Based Photoreceptors

W. W. Wang, G. Knopf, A. S. Bassi, U. of Western Ontario, Canada

A bidirectional, speed selective motion detector that exploits bioelectronic photoreceptors is described. Each photoreceptor is a multi-layered structure composed of a thin bacteriorhodopsin (bR) film sandwiched between two Indium Tin Oxide (ITO) electrodes. As a light sensitive protein, bR exhibits a differential response to temporal changes in the light intensity. The measured peak photovoltage is linear over a light power range of 0.1mW to 0.1W. The photoreceptor responsivity is measured over frequencies from 4 Hz to 400 Hz. Binary pulse correlation is used to identify the direction of movement and the pulse widths are used to compute the speed. The measured range of speed, in two directions, is 20 mm/s to 80 mm/s.

09:48—10:06

Towards Micro and Nano Manipulation Systems: Behaviour of a Laminated Polypyrrole (PPy) Actuator Driving a Rigid Link

S. W. John, G. Alici, U. of Wollongong, Australia

Conducting polymer actuators, such as Polypyrrole (PPy), incorporated into the structure of a manipulation system may be able to achieve micro and nanoscale precision, by avoiding effects such as backlash or friction. As a step towards this goal, laminated PPy actuators were varied in size and their behavior investigated while constantly loaded by a rigid link. This behavior has been evaluated in terms of the bending angle and force outputs of the actuator. It was found that the bending angles varied with length, but displayed unexpected trends due to the loading effects on the PPy. Force output of the actuators was also measured, with unloaded PPy producing greater force across all lengths than the near constant output of loaded PPy, attributable to the polymer and load interface.

Novel Displacement Measurement Technique of the Heterodyne Laser Interferometer for Nano Positioning

H.-S. Choi, J.-P. La, K.-H. Park, Gwangju Inst. of Science & Tech., Korea

This paper describes a novel displacement measurement technique to increase the measurement speed compared with the conventional arc-tangent method in the heterodyne laser interferometer. The proposed method can reduce the calculation load because the PWM signal has linear relation between the phase differences, while the non-linear function such as arc-tangent is required to demodulate the sinusoidal interferent signal. The brief analysis and measurement scheme of the system, and the experimental result using a Zeeman stabilized He-Ne laser are presented. They demonstrate that the proposed displacement measurement technique is proved to be faster and more robust than the conventional arc-tangent method.

10:06—10:24

Quasi-Static Positioning of Ionic Polymer-Metal Composite (IPMC) Actuators

Z. Chen, X. Tan, Michigan State U., *M. Shahinpoor,* U. of New Mexico, USA

Ionic polymer-metal composites (IPMCs) generate large bending motions under a low driving voltage (about 1 V). In this paper quasi-static actuation of IPMC is investigated with the goal of precise positioning. It is found that IPMC exhibits hysteresis between its bending curvature and the applied quasi-static voltage. The Preisach operator is proposed to model the hysteresis, and its density function identified experimentally. An open-loop positioning strategy is presented based on efficient inversion of the Preisach operator and its efficacy is demonstrated by experimental results. Finally a cascaded model structure is proposed to capture both the hysteresis and the dynamics of IPMC actuators.

A Comparative Study of Image Comparison Methods Embedded by Smart Surveillance Systems

M. V. Le, P. D. Le, B. Srinivasan, Monash Univ., Australia

A more reliable image comparison method means it is more tolerant to different types of noise (i.e. random and structured noise) and transformations in indicating the similarity and difference between two images. In this paper, we carry out a comparative study between two image comparison methods: IQM-CIM and IQME-CIM in terms of how well each method tolerates structured noise, variation of image contrast and distortion caused by affine transformations. Our experiments show that the IQM-CIM method is more tolerant to affine transformations than the IQME-CIM method. Meanwhile, the IQME-CIM method is more robust than IQM-CIM method in cases of images distorted by a wider range of the image contrast, and a higher intensity level of structured noise.

10:24—10:42

Towards Automating Micro Cellular Detection Process Using Micro Vortex Pump Arrays

R. Lam, K. F. Lei, L. Miao, Z. Dong, W. C. Law, Y. K. Suen, W. J. Li, A. Ho, S. K. Kong, The Chinese Univ. of Hong Kong, Hong Kong

This paper reports a polymer based microfluidic analysis system integrated with three micropumps and a surface plasmon resonance (SPR) biosensor for detecting the specific binding of biomolecules and qualitatively monitoring of cell adhesion on the sensor surface. Two experiments, 1) monitoring the reaction between BSA-BSA antibody, and 2) monitoring the activities of living cells in the presence or absence of trypsin in RPMI-1640 medium, were conducted to show the feasibility of real-time cellular and molecular detection. Based on these successful experimental results we have also developed a computer-controllable vortex micropump system that will eventually automate ….

Design and Experiment of Range-Extended Fiber Fabry-Perot Interferometer Utilizing the Second Harmonic Displacement Modulation

S.-K., Hung, E.-T. Hwu, National Taiwan U., *M.-Y. Chen,* China Inst. of Tech., *L.-C. Fu,* National Taiwan U., Taiwan

This paper proposes a new modulation scheme using high order harmonic information to solve the so-called ambiguity problem of interferometry. To start with, we build a Fiber Fabry-Perot Interferometer to serve as a displacement sensor system, which has 70-microm measurement range with 30nm RMS resolution. The experimental result shows that the proposed scheme has the ability to extend the measurement range beyond the limit of the wavelength while keeping the naturally high resolution of interferometry.

MA5

Nanoscale Manipulation, Assembly and Synthesis

Windjammer 2-3 (09:30–10:42)

Bradley J. Nelson, Switzerland — CHAIR

Lonnie J. Love, USA — CO-CHAIR

MEMO

Kinematic Design of a Novel 3-DOF Compliant Parallel Manipulator for Nanomanipulation — 09:30–09:48

Y. M. Li, , Q. Xu, U. of Macau, Macao SAR, China

A new 3-DOF compliant parallel manipulator (CPM) has been proposed for 3-D nanomanipulation. The system is constructed by a proper selection of components, and analyzed via the established pseudo-rigid-body model, based upon which the kinematic models are performed, and the CPM workspace is determined in view of the physical constraints. One of the advantages of the presented CPM is that it provides a regular like workspace with a maximum cuboid defined as usable workspace inscribed and one isotropic configuration involved. Moreover, the architecture design of the CPM to achieve a maximum usable workspace is carried out, and the dexterity performance is evaluated. Simulation results show that the compact CPM can perform a dexterous manipulation …

Fractal Compression and Adaptive Sampling for Atomic Force Microscopy — 09:48–10:06

H.-M. Cheng, G. T.-C. Chiu, Purdue Univ., USA

In typical scanning probe microscopy, the properties of interest are presented as a 3-D image. With the total number of samples remains constant, there is a trade-off between image size and resolution. Given the scanning mechanism, the time needed to image an area depends mainly on the number of samples and the size of the image. The slow imaging speed is further complicated by the drifts associated with the sample and the piezo suspension. It is therefore desirable to improve the imaging speed with limited impact to the resolution of the portion of the sample that is of interested. By utilizing an adaptive sampling scheme with fractal compression technique, we have demonstrated that the number of samples can be significantly reduced with minimal impact to the image quality.

Selective Eradication of Individual Carbon Nanotubes from Vertically Aligned Arrays — 10:06–10:24

A. Subramanian, L. Dong, B. J. Nelson, Swiss Federal Inst. of Tech. (ETH), Zurich, Switzerland

Selective eradication is presented as a postprocessing technique for as-grown vertically aligned carbon nanotubes (CNTs) for removing unwanted individual nanotubes in order to generate desired patterns. A scanning anode is applied to select a nanotube in a CNT emitter array. Using a saturated emission current, a nanotube emitter can be removed in a controlled way. Vertically aligned single multiwalled carbon nanotubes (MWNTs) are realized using a combination of e-beam lithography and plasma-enhanced chemical vapour deposition (PECVD) growth. The scanning anode is actuated with a 3-DOF nanorobotic manipulator with nanometer resolution inside a scanning electron microscope

Characterization of Bio-Synthesized Mangetic Nanoparticles — 10:24–10:42

L. J. Love, L. Yeary, J. W. Moon, T. J. Phelps, A. J. Rondinone, Oak Ridge National Lab., USA

This paper describes a novel methodology for bacterial synthesis of a wide range of magnetite-based magnetic nanoparticles. First, this approach is highly scalable and low cost enabling production of large volumes of nanoparticles. Second, like the chemical co-precipitation technique, biologically synthesized materials have the ability to dope magnetite with a wide range of elements enabling fine control over magnetic and thermal properties of the particles. Third, bacterial synthesis enables control of particle sizes from 10 nm to 100 nm. Finally, we show that some forms of the bio-synthesized materials have a significantly higher saturation magnetization than typical chemically synthesized materials.

MB1	Automotive Systems		Human -Machine Interfaces I	MB2
	Big Sur 1 (11:00—12:30)		Big Sur 2 (11:00—12:30)	
	Torsten Bertram, Germany	CHAIR	Hideki Hashimoto, Japan	
	Nader Sadegh, USA	CO-CHAIR	Max Meng, Hong Kong	

Precision Stopping Control of Automated Bus with Pneumatic Brake System

F. Bu, H.-S. Tan, U. of California, Berkeley, USA

Precision stopping is an important automated vehicle control function that is critical in applications such as precision bus docking and automated truck or bus fuelling. Such applications require specific attention to brake control since the characteristics of a typical pneumatic brake system of a heavy vehicle is inherently nonlinear with large uncertainties. This paper describes the precision stopping problem, details the Indirect Adaptive Robust Control (IARC) design for a bus with pneumatic brake system, and reports the successful implementation of a bus precision docking demonstration.

11:00—11:18

Fuzzy Control of a New Tendon-Driven Exoskeletal Power Assistive Device

K. C. Kong, D. Y. Jeon, Sogang Univ., Korea

This paper proposes a tendon-driven exoskeletal power assistive device to reduce some problems of the existing exoskeletal power assistive equipment. In addition, this paper suggests a caster walker carrying heavy peripheral devices and maintaining stable balance of the user at the same time. A muscle fiber expansion signal is used to control this device in order to compensate for the delay time of motors and perform an easy assistance by sensing the user's action in advance. The muscle fiber expansion signal has the characteristics that the signal is ahead of action and in proportion to joint torque. A fuzzy control method is applied to control the proposed exoskeletal assistive device. This paper also describes a number of action tests such as sitting, standing, and walking.

Driver-Input Sensor Selection and Topologies for Fault-Tolerant Drive-By-Wire Applications

N. Y. Lii, S. Sturm, BMW AG, *T. A. Coombs,* Cambridge Univ., UK

Drive-by-wire applications, such as brake-by-wire, steer-by-wire and throttle-by-wire, are becoming increasingly popular in the automotive industry. This work examines different sensors for driver-input systems for Drive-by-wire, as well as the integration of these sensors to achieve the fault-tolerance necessary for such safety-critical applications. A pedal test bed is constructed for studying the integration of similar and dissimilar sensors. Two sensor integration topologies involving multiple sensors, similar and dissimilar, are proposed to demonstrate different possibilities of fault-tolerant systems. The merits and limitations of both systems when coping with sensor and mechanical faults and failures are presented.

11:18—11:36

Emotional Evaluation of Frisky Robot Based on SD and Biosignal Method

H. Hashimoto, D. Takeda, Y. Ohyama, Tokyo U. of Tech., *M. Saito,* Sony, *C. Ishii,* Kogakuin U., *M. Niitsuma, H. Hashimoto,* U. of Tokyo, Japan

This paper describes the emotional evaluation of a frisky robot that weaves around its human owner; the evaluation is based on the SD (Semantic Differential) method and the RRV(R-R wave variance) method using electrocardiograms (ECG) as the biosignal source. The SD method is effective to measure emotion, and the RRV method is suitable for investigating the physiological state from the heartbeat. The SD method represents that humans show a significant response only when the robot weaves, not when it simply shadows the human. Furthermore, it is confirmed that these methods are correlated and the RRV method is effective in real time evaluation.

Optimization of the Fuel Consumption of a Parallel Hybrid Electric Vehicle

B. Khan, Schlumberger, *N. Sadegh, J. Meisel,* Georgia Inst. of Tech., USA

In this paper we present a novel control strategy for optimal power management of parallel Hybrid Electric Vehicles based on fuel efficiency. In particular, the proposed strategy optimally distributes the required drive torque between the available power sources, which in the present study consist of an electric motor and an IC engine. This is achieved by first estimating the power demand at the wheels and then determining a set of solution points that meet the constraints from which the optimal solution is subsequently chosen. The strategy was implemented in a simulation software package and compared to the thermostat strategy the optimization strategy reduced the fuel consumption by 55.7 % on a highway cycle and by 42.4 % on a city cycle.

11:36—11:54

Development of a Medical Telediagnostic System with Tactile Haptic Interfaces

N. Methil-Sudhakaran, Y. Shen, R. Mukherjee, N. Xi, Michigan State U., USA

This paper aims at developing a tele-breast cancer diagnostic system with tactile sensing and haptic feedback. An anthropomorphic, robotic hand that mimics a human hand performing a clinical breast exam was developed to perform the same. A high resolution optical tactile sensor was developed to obtain information regarding the texture and the relative surface variations on an object. This information can be fed back desirably to the physician via a newly developed electro-tactile haptic device. Experimental results were obtained by testing these devices on an artificial breast model to detect tumors.

Modeling and Control Analysis of Toyota Hybrid System

J. Liu, H. Peng, Z. Filipi, U. of Michigan, Ann Arbor, USA

Toyota Hybrid System is the innovative powertrain used in the current best-selling hybrid vehicle on the market—the Prius. It uses a split-type hybrid configuration which contains both a parallel and a serial power path to achieve the benefits of both. The main purpose of this paper is to develop a dynamic model to investigate the unique design of THS, which will be used to analyze the control strategy, and explore the potential of further improvement. A Simulink model is developed and a control algorithm is derived. Simulations confirm our model captures the fundamental behavior of THS reasonably well.

11:54—12:12

Support System for Skill Acquisition of Machine Operation by Gradual Reduction of Assist

R. Hayashi, S. Tsujio, Y. Yu, Kagoshima Univ., Japan

The aim of this research is to investigate the new approach to the development of the system which supports inexperienced operators who are trying to acquire the operation skill. In this approach, we consider the support system which has the following functions; Firstly, it works to lighten the burdens to the inexperienced operators, by using a controllable assist. Secondly, it works to reduce gradually the effect of the assist according to the operator's skill. In this paper, we deal with an operation problem of a rotary arm with a pendulum and try to construct such a support system.

Load-Following Improvement of Fuel Cells with Fast Transient OCC Inverter (I)

J. Wen, K. M. Smedley, U. of California, Irvine, *M. A. Pai,* U. of Illinois, USA

Fuel cells typically have much longer response time than the electrical grid, which may cause a voltage disturbance when the load has a sudden change. The situation can be alleviated via proper power control. This paper utilizes the fast nature of inverter to improve the fuel cell load-following capability. A linear SOFC model and a large signal OCC inverter model are used to analyze the response of the fuel cell/inverter system to a load step. A closed-loop power control is proposed to achieve a fast system dynamic response, and a comparison is made with the conventional power control. The results indicate that with a parallel capacitor of appropriate value, the proposed control is able to improve the load-following capability of the fuel cell to a load transient in a limited range.

12:12—12:30

3D "Sound Spot" Forming by Multi Axis Speaker Array for Environmental Robot

K. Sakaya, H. Mizoguchi, T. Toba, Tokyo U. of Sci., *S. Kagami,* AIST, Japan

This paper describes 3D sound field generation by multiple lines speaker array. In order to realize a novel hands-free sound interface for human-machine systems, the authors are studying multiple lines speaker array. A technique to transmit sound towards a specified direction by speaker array of one straight line is known as beam forming. The authors propose an idea that two and three orthogonal lines speaker array can form spot-like small area of higher sound pressure level. We conduct simulation of two and three lines speaker array. Based upon the results, the authors construct 32 by 2 lines array and 32 by 3 lines array. And we actually measure 3D distribution of sound pressure level by the constructed arrays. Results of the measurement also support the feasibility of our idea.

MB3	Precision Piezoelectric Actuators		Advanced Machine Vision Applications I	MB4
	Big Sur 3 (11:00—12:30)		Windjammer 1 (11:00—12:30)	
	Metin Sitti, USA	CHAIR	Michael Bailey-Van Kuren, USA	
	Shih-Ming Yang, Taiwan	CO-CHAIR	Johne Parker, USA	

A Piezoelectric Unimorph Actuator Based Precision Positioning Miniature Walking Robot

K. J. Son, V. Kartik, J. Wickert, M. Sitti, Carnegie Mellon Univ., USA

This paper proposes a precision positioning miniature walking robot using piezoelectric unimorph actuators. The theoretical working equations of a uniform piezoelectric unimorph beam are derived. The modal superposition method is used to determine the response of the forced transverse vibration of the beam. Two standing waves corresponding to the third and fourth bending vibration modes are utilized to achieve the bi-directional walking mechanism for a miniature positioning robot. Design strategies and the fabrication method for the proposed walking robot are introduced. Preliminary performance tests of the robot prototype are carried successfully, and the robot can move forward with the speed of 5.86 cm/sec velocity and backward with 3.37 cm/sec.

11:00—11:18

A Projector–Vision System for Combined Manual and Automated Demanufacturing (I)

M. Bailey-Van Kuren, Miami Univ., USA

The electronics recycling industry utilizes manual methods for dismantling products. A demanufacturing projector-vision system is proposed to improve the work cell efficiency with automated processing methods. The projection-vision system identifies the used products and identifies the product surface for robotic processing. A prototype of the work cell was implemented. The system facilitates processing of used goods to meet dynamic product or material demand. The projector-vision based system was integrated into an existing modeling framework for robotic processing. The application of projector-vision technology improves the accuracy of recovered material databases and improves the automated processing of used material streams.

A Traveling-Wave Linear Piezoelectric Actuator with Enclosed Piezoelectric Elements

J. R. Friend, Monash U., Australia,
K. Nakamura, S. Ueha, Tokyo Inst. of Tech., Japan

A 1.8 cc silent bidirectional traveling-wave self-moving linear microactuator is shown to be capable of generating a sliding velocity of 0.22 m/s and sliding force of 1.1 N. The generation of a radial traveling wave about the circumference of the actuator, akin to a ring, is shown to exist despite the unusual shape, and the presence of traveling wave motion along the output face is also shown to exist. By using short-time sinusoidal signals, slider displacements as small as 82~nm were obtained from the actuator, and by using DC input, displacements of up to +/-107 nm were obtained, suggesting a way to obtain sub-nanometer positioning accuracy over arbitrary sliding distances.

11:18—11:36

Integration of an External Vision System into a 2D Spacecraft Testbed for Feedback Control (I)

M. Gonzales, Lockheed Martin Space Systems, *W. Du,* San Jose State U., USA

This paper discusses the integration of an external vision system (EVS) into an existing two-dimensional spacecraft (2D) testbed to provide full range inertial attitude measurements for the 2D spacecraft experiment. The work involved familiarization with the EVS and its capabilities, selection of targets, processing of vision system measurements, vision data transmission, and assessment of the signal quality of the EVS. These procedures are important steps toward implementation of real-time, closed-loop pointing and slewing of the spacecraft testbed. Finally, full 360 degree coverage was demonstrated culminating successful integration of the EVS into the 2D spacecraft testbed.

Adaptive Robust Precision Control of Piezoelectric Positioning Stages

J. Zhong, B. Yao, Purdue Univ., USA

Positioning stages using piezoelectric stack actuator (PEA) have very high theoretical bandwidth and resolution. However, as the total length of travel increases, nonlinear dynamics due to inherent hysteresis starts to dominate. In this paper, we separate the fast and slow dynamics of the total displacement and propose a simple first-order model. By approximating the hysteresis mapping with simple functions, it is linearly parameterized for subsequent adaptive robust controller design. Experimental results from tracking control of sinusoidal and point-to-point trajectories show tracking error on the magnitude of the sensor noise level and demonstrate the effectiveness of the approach.

11:36—11:54

Artificial Color Contrast for Machine Vision and Its Effects on Feature Detection (I)

K.-M., Lee, Georgia Inst. of Tech., *W. Daley,* Georgia Tech. Res. Inst.
Q. Li, Georgia Inst. of Tech., USA

Color information is useful in vision-based feature detection, particularly for applications involving natural objects. One of the factors influencing the success rate of color vision in detecting a target is its ability to characterize the color. When unrelated features are very close to the target in the color space, which may not pose a problem to an experienced operator, they appear as noise and often results in false detection. Motivated by the ability of the human to perceive fine gradation of a variety of color especially for natural products, we develop a method to create artificial color contrast between features in color space for highlighting the target while suppressing surrounding noise. ….

A New Type of Piezoelectric Linear Motor: The Stator Design

Y. Ting, L.-C. Chen, C.-C. Li, J.-L. Huang, Chung Yuan Christian U., Taiwan

A new type of piezoelectric linear motor driven by bimorph actuator is developed. The stator fundamentally consists of a meander-line structure and a gear teeth mounted on the meander-line structure is focused in this article. The meander-line structure with bimorph actuators in a line driven by two sets of AC power with phase difference can generate traveling wave. The traveling wave is transferred to the carriage by the gear teeth, and thus forms a linear motor. Modeling of the meander-line structure is derived. Simulation by ANSYS for several different key parameters is presented.

11:54—12:12

Effects of Color Characterization on Computational Efficiency of Feature Detection with Live-Object Handling Applications (I)

Q. Li, K.-M. Lee, Georgia Inst. of Tech., USA

This paper presents a machine vision algorithm that utilizes the principal component analysis technique to characterize target features in color space from a set of training data so that the color classification can be done accurately and efficiently. The method, referred to here as statistically based fast bounded box (SFBB), has significant potential in agriculture and food processing applications where color variability often renders grayscale-based algorithms difficult to work. We examine the effects of the color characterization on computational efficiency by comparing against two commonly used algorithms; RCE neural network and support vector machine. Comparison among these methods demonstrates that SFBB is relatively easy to train and effective, as with sufficient training data it requires no additional optimization steps.

Double-Microcantilever Design for Surface Stress Measurement in Biochemical sensors

T.-I. Yin, S. M. Yang, National Cheng Kung Univ., Taiwan

Microcantilever biochemical sensor with embedded piezoresistor has been proposed to measure the surface stress change from biochemical reaction. However, the sensor performance is adversely influenced by the self-heating of piezoresistor and biaxial surface stress loading. A mechanics model of piezoresistive microcantilever subject to surface stress loading is developed in this paper. A double-microcantilever design composed of the top immobilized microcantilever and the bottom sensing microcantilever is also proposed such that the surface stress loading can be converted to a concentrated force loading. The effect of biaxial surface stress can thus be limited to the immobilized microcantilever with the uniaxial strain in the sensing microcantilever.

12:12—12:30

Efficient 3-D Characterization of Surface Defects in Smooth Specular Coatings (I)

J. Parker, U. of Kentucky, *P. Gnanaprakasam,* SMC, Inc.
S. Ganapathiraman, Z. Hou, U. of Kentucky, USA

Many smooth, specular coatings are subjected to considerable performance demands and manufacturers spend significant sums to monitor and repair surface quality. Additionally, changing product specifications and environmental regulations continue to affect the processing parameters that influence surface appearance and quality. Therefore, it is vital to develop robust methods to monitor surface quality on-line and continuously examine the processes that affect surface appearance in real time. This paper presents a cost-effective machine vision system design that utilizes surface reflectance models as a rational basis. Experimental & numerical investigations confirm that diffuse images yield...

MB5

Micro and Nano Systems Design and Modeling

Windjammer 2-3 (11:00—12:30)

Wen J. Li, Hong Kong — CHAIR

Yi Su, Singapore — CO-CHAIR

MEMO

Design of a Delta–Sigma Bandpass Demodulator for a Z-Axis MEMS Vibrational Gyroscope

E. Nunzi, U. di Perugia, *R. Antonello,* U. of Padova, *R. Oboe,* U. of Trento, *P. Carbone, E. Lasalandra, G. Spinola, L. Prandi,* ST Microelectronics, Italy

11:00—11:18

This paper describes the design of a Delta-Sigma bandpass demodulator for a Z-axis MEMS vibrational gyroscope. The sensing of the Coriolis force and, in turn, of the Z-axis rotational speed, is performed in closed loop fashion, by measuring the restoring force needed for keeping the sensing mass at the equilibrium position. The restoring force is applied to the sensing mass through a quantized actuation signal, which is obtained from the output bit stream of a band– pass Delta–Sigma converter, containing the information of the Coriolis force. The design of the sensing control loop and simulation results regarding the signal–to–noise ratio achievable with the proposed design is reported. ….

Automatic Mixed-Dimensional MEMS Modeling

Y. Su,C. S. Chong, Inst. of High Performance Computing, Singapore

11:18—11:36

The pre-processing stage of creating and preparing the finite element mesh for MEMS analysis poses various challenges towards full automation. This paper presents an automatic process to generate the mesh of a MEMS model by using a geometric transformation, known as the block Cartesian abstraction, which can be further decomposed into a mixed-dimensional equivalent. This is then meshed using a new grid-based algorithm resulting in a mixed quadrilateral and hexahedral mesh, which reduces the computational requirement during analysis as compared to using a full hexahedral mesh. As the mesh is structured, it can also be used as a platform for coupled-domain analysis.

Self-Built Multilayer Aligner for Imprint with Finite Element Method Simulation

C.-T. Pan, C.-C. Cheng, C.-Y. Chen, L.-H. Cheng, K.-L. Sher, National Sun Yat-Sen U., Taiwan

11:36—11:54

In this paper, a new method combining imprint lithography and multiimprint was discussed to improve the generic TFT process and develop an alignment machine for multilayer imprint and in order to decrease the times of the experiment, a new simulator is offered, too. A simple theorem is employed to complete a low cost alignment machine with alignment accuracy to 1 μm. Besides, in order to develop new TFT imprint photoresist, three kind of materials, AZ-series, photoresist (a positive photoresist), HOSP (Hygrido Organic Siloxane Polymer) and SE-812, are tested for imprint and evaluate the applications of these materials in the future. ….

Modeling and Simulate Analysis for Micro-Thermoelectric Generator

R. Song, W. Li, C. Yang, Y. Liu, Zhejiang Univ., China

11:54—12:12

The model for calculating the output power and efficiency for micro- thermoelectric generator was built up based on the consideration of such factors as heat source resistivity, thermal conduct overlay piece and current conduct layers and the influence of Thomson effect. The constructed simulate model and the comparison between perfect model and actual simulate model show that these factors above have notable influences for output power of micro-thermoelectric generator, which was confirmed by experiments.

On Recent Developments for High-Speed Atomic Force Microscopy

G. Schitter, G. E. Fantner, J. H. Kindt, P. J. Thurner, P. K. Hansma, U. of California, Santa Barbara. USA

12:12—12:30

The atomic force microscope (AFM) is limited in imaging speed by the bandwidth and dynamic behavior of the actuators and mechanical parts. For high-speed imaging all AFM components have to be optimized in performance. Here, we present improvements of the force sensor, the scanner, the controller, and the data acquisition system. By combining all these improvements, the next generation AFMs will enable imaging speeds more than two orders of magnitude faster than current commercial AFM systems.

MC1	Vehicle Control		Human -Machine Interfaces II	MC2
	Big Sur 1 (14:00—15:30)		Big Sur 2 (14:00—15:30)	
	Ranjan Mukherjee, USA	CHAIR	Wayne Book, USA	
	Vincenzo Delli Colli, Italy	CO-CHAIR	Hideki Hashimoto, Japan	

Guardrail Collision Avoidance for Autonomous Robotic Vehicles by Automatic Steering Control Using an Explicit Force Control Algorithm

S. Jung, Chungnam National Univ., Korea
T. A. Lasky, *T. C. Hsia*, U. of California, Davis, USA

In this paper, an explicit PID force control approach is presented for automatic steering control of an autonomous robotic heavy duty vehicle to avoid collision with guardrails. The desired distance is provided by an explicit PID controller based on a virtual force error. Simulation studies are performed for controlling a steering angle of the bicycle model of the robotic vehicle to maintain the virtual desired force and thus the desired offset from the guardrail.

14:00—14:18

Evaluation of a Teleoperated Haptic Forklift

M. Kontz, Georgia Inst. of Tech., *J. Beckwith*, Simbex
W. Book, Georgia Inst. of Tech.USA

A haptic teleoperation scheme has been designed and implemented on a hydraulically actuated lifter which is laboratory version of a forklift truck. This control scheme has two novel features. It produces virtual fixtures based on measurements from a proximity sensor located on its end effector. Secondly, the control system has the ability to switch between position and rate modes during normal operation. In order to evaluate the effectiveness of these features, a series of human factors tests were conducted. Twenty test subjects participated in these experiments. Statistical analysis of the results indicates that both of the aforementioned novel features could enhance an operator's ability to conduct pick and place maneuvers using a forklift truck.

Wheel Slip Prevention Control by Sliding Mode Control for Railway Vehicles (Experiments Using Real Size Test)

H. Yamazaki, Y. Karino, Railway Tech. Res. Inst.
M. Nagai, T. Kamada, Tokyo U. of Agriculture & Tech., Japan

In the design of brake control systems, it is quite important to consider the robustness because there exists the model's uncertainties which result from nonlinear characteristics of adhesion forces between wheel and rail, and friction coefficients of brake materials. This paper will present the experimental results about the new wheel slip prevention control by the sliding mode control theory. The experiments for the proposed wheel slip prevention control were performed to compare with the conventional control laws. The experimental results proved the effectiveness of the proposed control as compared with the conventional ones, and showed high brake performances.

14:18—14:36

A Human-Robot Shared Control in Single-Master Multi-Slave Tele-Micromanipulation System

G.Hwang, P. T. Szemes, U. of Tokyo, *N. Ando*, AIST
H. Hashimoto, U. of Tokyo,Japan

Our approach toward the advanced tele-micromanipulation is developing the single-master multi-slave tele-micromanipulation system based-on the shared control framework. A single-master (PHANToM haptic device) and multi-slaves (6 D.O.F parallel manipulator) configuration introduces a mapping problem which can be serious for some cooperative manipulations. The position/force virtual mapping method is implemented in the single-master dual-slave environment to realize the human-robot shared internal force control framework while grasping task. A pick-and-place experiment proves the improvement of internal force regulation by the proposed shared control framework.

Sliding Mode Control with Disturbance Observer for Antilock Braking Systems

J. K. Hwang, Woosuk Univ., *K. H. Oh*, Defense Quality Assurance Agency
C. K. Song, Gyeongsang National Univ., Korea

A sliding mode controller (SMC) with a disturbance observer (DOB) is developed for control of the anti-lock brake system (ABS) for passenger vehicles. Hydraulic brake dynamics as well as vehicle model parameter variation are considered in the developed control method. A SMC is designed to attain a desired wheel slip ratio without consideration of the hydraulic brake dynamics. A DOB is inserted into the SMC to reduce effects of un-modeled dynamics of the hydraulic brake system and the model parameter variation. The proposed ABS control shows good results of simulations on ABS brake dynamics, model parameter variation, and external disturbances.

14:36—14:54

Hand Force Feedback System to Recognize Surrounding Objects for Safe Walking

H. Hashimoto, M. Saito, *A. Sasaki,* Tokyo U. of Tech., *C. Ishii*, Kogakuin Univ.
M. Niitsuma, H. Hashimoto, Univ. of Tokyo, Japan

This paper presents a user-friendly hand force feedback system to recognize surrounding obstacles around the elderly to making walking safer. The system is implemented on a joystick mounted on a walker. The user is able to recognize the surrounding spatial information from the repulsive force generated as feedback on the joystick. The system is based on the generation of a virtual potential field that corresponds to the distance and direction to the obstacle is employed. Through the experimental results, it is found that the practice time of the user to learn basic operation of the system is sufficiently short.

A Multipurpose Platform for HIL Testing of Safe Relevant Railway Subsystem

L. Pugi, M. Rinchi, M. Malvezzi, Univ. of Florence, *G. Cocci,* UTMR, Italy

Trenitalia SPA, in collaboration with the University of Florence has invested a considerable amount of resources and know-how to develope a modular platform called MI-6 for HIL testing of WSP and other safe relevant on board subsystem like odometry and or ATP/ATC systems. In this paper the authors describe the main features of the rig, that have been successfully used for the real time simulation of the odometry algorithm of the italian ATP system, named SCMT (Sistema Controllo Marcia Treno) and for the HIL testing of complete WSP systems including Electronic Control units, sensors and electro-pneumatic devices. Particular attention was devoted in the design phase of the rig to the optimization of both real time software and actuators.

14:54—15:12

Study on a Portable Pointer for Positional Data Acquisition

K. Ioi, Kinki Univ., *Y. Sato*, Tokyo Electron AT, *S. Miyoshi*, Kinki Univ.Japan

This paper presents a new portable pointing device for positional data acquisition. Since human-friendly welfare systems are seriously desired around the world, we have developed a device to aid physically handicapped persons. Our device can be used anywhere and anytime because it is rarely affected by such environmental conditions as light and noise. First, we describe the mechanism of our proposed pointing device, and explain its basic principle of coordinate acquisition. Next, we propose a concrete pointing procedure that indicates a desired object and a calibration method to obtain the accurate coordinates from points pointed at. Then, we show the experimental results of the pointing device and confirm that it can accurately acquire the coordinates of a desired object. Finally, we conclude with the usefulness of the pointing device.

Fuzzy Longitudinal Traction Control

V. Delli Colli, G. Tomassi, M. Scarano, Univ. of Cassino, Italy

The traction control increases stability, safety, efficiency and range of EVs preventing slippage in acceleration and permitting to use high-efficiency low drag tires. The presented approach offers the performance of the well-recognized techniques and a simple implementation. This paper considers the longitudinal control of each driven wheel of the vehicle, and it bases the control on an adherence observer and a fuzzy controller of the adherence derivative. The controller performs well in a very wide operating range without a priori knowledge of road conditions. Moreover, the experimental tests evidenced that the control has a good response to sudden changes in the adherence curve of the road.

15:12—15:30

Control and Interface between an Exoskeleton Master Robot and a Human Like Slave Robot with Two Arms

W. K. Lee, D. H. Song, S. Jung, Chungnam National Univ., Korea

This paper presents hardware implementation of interfacing two robots: an exoskeleton motion capturing master robot and a motion following slave robot. The master robot captures human motions operated by a human operator who wears the exoskeleton device. The slave robot is controlled to follow the motion after the master robot. Control hardware is implemented on an FPGA chip to access multi-joints of the robot. Experimental results show that motions following tasks are successfully achieved in real time. Problems in implementation are addressed.

MC3	Precision Electromagnetic Actuators		Advanced Machine Vision Applications II	MC4
	Big Sur 3 (14:00—15:30)		Windjammer 1 (14:00—15:30)	
	I-Ming Chen, Singapore	CHAIR	Johne Parker, USA	
	Guilin Yang, Singapore	CO-CHAIR	Winncy Du, USA	

Optimal Design and Control of a Voice Coil Motor Driven Flexure Hinge for AFM Actuator

W. -S. Youm, GIST, *S. -Q. Lee*, ETRI, *K. -H. Park*, GIST, Korea

A systemic design procedure of general VCM (Voice Coil Motor) to _ne z-axis AFM (Atomic Force Microscopy) actuator is introduced for fast and precision actuation. Design parameters are selected based on the dynamic model of VCM and _exure hinge, and design process is proceeded in point of fast and precision actuation performances. To verify the performance of the designed actuator, frequency response of the actuator and contact type AFM image of a standard grid sample are performed.

14:00—14:18

Accelerations of a 3D Tracking Method for Non-Rigid Objects

J. Masaki, N. Okada, E. Kondo, Kyushu Univ., Japan
M. Hebert, Carnegie Mellon Univ., USA

This study aims to track a non-rigidly deformable object in real-time using successive range images. Our approach assumes that the object is globally rigid and partially non-rigid during a short interval between 3D snapshots. The tracking process consists of 3 steps; estimating the rigid transformation by ICP algorithm, extracting the non-rigidly deformed areas, and estimating their deformation vectors by Thin Plate Spline Robust Point Matching (TPS-RPM) algorithm. In our past research, it took mach time for estimating the deformation vectors. Then, in this paper, techniques for accelerating the tracking process are described.

A New EMV System Using a PM/EM Hybrid Actuator (I)

H. -J. Ahn, S. -Y. Kwak, J. -U. Chang, D. -C. Han, Seoul National U., Korea

In this paper, we develop a new EMV (electro mechanical valve) system using PM/EM (permanent magnet / electro magnet) hybrid EMA (electro magnetic actuator) and achieve the soft landing and the fast transition of the system using a simple PID control. Against the existing EMA using only the EM, the proposed actuator has several advantages like the PM biased AMB (active magnetic bearing) system. First, theoretical model of the proposed EMV system is derived and FE (finite element) analysis is performed to verify the theoretical model. Then, a test rig and a valve control system are built and the dynamic characteristic of the proposed EMA is identified. Finally, the soft landing and the fast transition of the system are achieved experimentally.

14:18—14:36

Real-Time Automated Visual Inspection of Fabric Inhomogeneities

Z. Hou, J. Li, J. Parker, Univ. of Kentucky, USA

Defects in fabrics usually appear as inhomogeneities of fabric texture patterns. Accurate and efficient detection of these inhomogeneities is crucial for fabric manufacturers. Many sophisticated visual inspection methods have been introduced based on texture analysis algorithms. Unfortunately, only few of these are suitable for real-time fabric inspections due to the high computational cost. An efficient and robust fabric defect detection method is proposed in this paper. It is based on the fact that the presence of defects breaks the texture's homogeneity and changes the distribution of microedges in the edge map after the original texture image undergoes edge detection. The proposed method is implemented on a smart camera using its on-board processing ability to achieve fast inspection.

Torque Model for Design and Control of a Spherical Wheel Motor

K. -M. Lee, H. Son, Georgia Inst. of Tech., USA

This paper presents a method of deriving the torque model for a three degrees of freedom (3-DOF) spherical motor such as a variable-reluctance spherical motor (VRSM) or a spherical wheel motor (SWM). The SWM (much like the VRSM capable of offering three-DOF in a single joint) has the ability to spin continuously while the rotor shaft can be tilted arbitrarily. We derive a closed-form torque model and demonstrate its use for designing the switching controller based the principle of push-pull operation for the SWM. The closed-form torque model given here greatly reduces the torque computation, and simplifies the design of the switching controller. Illustrating through an example, the open-loop controlled SWM is essentially a 3-DOF in-wheel motor with an electronic gear transmission.

14:36—14:54

Binocular Fixation on Wide-Angle Foveated Vision System - Contour-Based Feature Generation from Space-Variant Image Using DFT

S. Shimizu, H. Jiang, S. Shimojo, J. Burdick, California Inst. of Tech., USA

This paper introduces a novel interactive vision system, which is suitable for cooperative works between the human and computer. This system acquires human-like binocular wide-angle foveated (WAF) information from a stereo camera head with special wide-angle optical lens and provides processed video signals both to the computers and to the user's sight simultaneously. The user can observe this unique information on 3D HMD. The developed vision system is quite applicable for the human brain and vision research like psychophysics. This paper proposes to carry out binocular fixation based on features extracted from contour images, and examines about scale, rotation and translation (SRT) invariant features generated from WAF space-variant images using DFT.

Design & Analysis of a New Variable Stator Pole for a DC Spherical Actuator (I)

C. K. Lim, L. Yan, I. -M. Chen, Nanyang Tech. Univ., Singapore, *G. Yang, W. Lin*, S'pore Inst. of Mfg. Tech., *K. -M. Lee*, Georgia Inst. of Tech., USA

A DC spherical actuator was developed recently in a bid to achieve 3 DOF motion within a spherical joint. The actuator consists of permanent magnet rotor poles and air-core stator poles. With the utilization of these poles, dramatic temperature dependence, non-linearity and hysteresis nature of ferromagnetic material can be avoided. This translates to system linearity that simplifies and enhances the control aspect of the system as a whole. Inevitably, the drawback on the other hand will be in the reduction of output force and torque. This paper presents a new conceptual pole design that allows tweaking of material composition within the coil.

14:54—15:12

Automated Tiny Surface Defect Detection Using DCT Based Enhancement Approach for Statistical Textures

H. -D. Lin, D.-C. Ho, Chaoyang U. of Tech., Taiwan

This research proposes a novel approach that applies DCT based enhancement for the detection of pinhole defects on SBL chips. A two-stage decomposition procedure is proposed to extract an odd-odd frequency matrix after a digital image has been transformed to DCT domain. The cumulative sum algorithm is then proposed to detect the transition points of the gentle curves plotted from the odd-odd frequency matrix. Experimental results show the proposed pinhole defect detection method can reach the pinhole defect detection rate by 90% and decrease the deviation of the defect areas by 90%.

Experimental Investigation on the Magnetic Field of a Permanent Magnet Spherical Actuator (I)

L. Yan, C. K. Lim, I. -M. Chen, Nanyang Tech. Univ., Singapore, *G. Yang, W. Lin*, S'pore Inst. of Mfg. Tech., *K. -M. Lee*, Georgia Inst. of Tech., USA

This paper introduces the experimental study on the magnetic field of a permanent magnet (PM) spherical actuator. A new type of testbed is developed to measure the three-dimensional (3D) magnetic flux density distribution of the rotor consisting of PM poles. The captured data are nondimensionlized and normalized so that they could be referred by similar rotor designs without regard to the specific dimensions of the poles. Furthermore, the measured data are presented visually in Cartesian coordinates, which facilitates the analysis of the magnetic field generated by the rotor.

15:12—15:30

Study on Contrast Evaluation Function of CMOS Digital Camera

G. Chen, M. Zhu, L. Guan, K. Zhang, Hangzhou Dianzi Univ.
G. Xu, Xidian Univ., *H. Shi*, Hangzhou Dianzi Univ., China

The definition evaluation function not only determines the auto-focusing validity of a whole system, but its algorithm determines the real time characteristic of the whole hardware. This paper analyses the imaging principle, and brings forward that the focusing characteristic curves should meet symmetry, single peak, high defocusing sensitivity, enough signal-to-noise ratio and little calculation quantity. The definition evaluation functions based on gray variety, gray entropy and differential grads are constructed respectively. Brenner function and absolute variance function have the optimal integrated capability. For higher precision and real time performance, a combined method based on Brenner function and absolute variance function is brought forward for focusing.

MC5

Micro Manipulation and Assembly

Windjammer 2-3 (14:00—15:30)

Georg Schitter, USA — CHAIR

Yoshio Yamamoto, Japan — CO-CHAIR

MEMO

Handling Processes in Microsystems Technology

S. C. Bou, A. Almansa, ARC Seibersdorf Res. GmbH, Austria

N. Balabanava, Z. Rymuza, Warsaw U. of Tech., Poland

14:00—14:18

Handling is a very important matter in microsystems technology, very especially concerning assembly of hybrid MEMS, where micro components need to be handled and integrated into the final device. Microhandling is a complex field, which consists of many different aspects which need to be taken into account. Relevant aspects include from types of microgripper actuation and working principles to different strategies for handling and positioning with micrometer accuracy, as well as the adhesion problems. This paper explains and clarifies all these aspects. Apart from that, this paper also presents some results of work done on material adhesion and tribological issues, dealing with the working surfaces of handling tools.

An Overview of the Micro-Manipulation System [mü]MAD

D. S. Haliyo, G. Venture, S. Régnier, J. -C. Guinot, Univ. Paris 6, France

14:18—14:36

The micro-manipulation system developed in Laboratoire de Robotique de Paris (LRP) is described in this paper. This system, called [mu]MAD, is based on the use of adhesion forces and inertial effects for handling of objects which range from 1 to 100μm. Moreover, enhanced user interaction is provided through a 6 dof haptic interface for force feedback remote handling. Some advanced features of [mu]MAD such as mechanical characterizations and sorting are also presented.

Development of Concentric Micro Manipulation System

Y. Yamamoto, Tokai Univ., Japan

14:36—14:54

Recently micro manipulation and nano manipulation techniques have drawn a lot of attentions because of their potential utilities not only in manufacturing fields but also in medical and bioengineering domains. Generally speaking, changing the orientation of a manipulation probe is considered far more difficult in such systems than changing the translational position alone, because such a rotary motion requires the probe tip be kept stationary. Facilitating a posture changing mechanism leads to a large scale apparatus or highly expensive system. This research is intended to provide a posture changing capability for micro manipulation at reasonable cost by introducing an offset planar hinge mechanism. The current report presents a prototype system which has recently been developed.

Optimal Control Based Active Force Sensing System for Micromanipulation

E. Winder, Y. Shen, N. Xi, Michigan State U., *W. Sheng*, Kettering Univ.

U. C. Wejinya, C. A. Pomeroy, Michigan State U. USA

14:54—15:12

This paper presents the development of an active force sensing technology for micromanipulation using in-situ polyvinylidene fluoride (PVDF) layers symmetrically bonded to the surface of a flexible cantilever beam structure. This beam has both sensing and actuating PVDF layers. The sensing layer detects the deformation signal due to external micro-force acting at the sensor tip. Using a LQR optimal feedback control scheme, a counteracting bending moment is generated by the actuating layer, balancing the deformation of the sensor beam. Furthermore, the micro-force value can be obtained by calculating the balance force.

New Challenges in Precision Positioner Development

X. Li, W. Wang, Z. Chen, Zhejiang Univ., China

15:12—15:30

The paper summarizes published researches on this subject and classifies them in light of positioner's main components. In Section I, the needs of precision positioner and the challenges it faces with are mentioned. Then in Section II, the respective features and limitations of typical actuators are given in details. The translation mechanisms like flexure hinges and some other special mechanisms are described in Section III. Measurement device is narrated in Section IV. In Section V, 3 types of positioners in practice are classified and their comparisons are made. As the conclusion, Section VI summarizes the directions for further researches.

MD1	Locomotion		Human-Centered Robotic Systems	MD2
	Big Sur 1 (15:45—17:15)		Big Sur 2 (15:45—17:15)	
	Jizhong Xiao, USA	CHAIR	Junji Furusho, Japan	
	Matthew D Summer, USA	CO-CHAIR	Guilin Yang, Singapore	

15:45—16:03

Design and Control of a Dexterous Biomimetic Multi-Limbed Walking Robot

M. Summer, R. Varley, J. Stiver, L. Davis, Harris Corp. – GCSD, USA

This paper introduces a multi-limbed walking robot, capable of vertical climbing, named RIDES (Remote Infrastructure Delivery & Entry System). An overview of the mechanical, electrical, and control architecture will be presented along with the current results. The primary mission of the robot is aimed at search and rescue operations in urban/industrial environments. It is anticipated that a large degree of dexterity is required to tackle complex indoor and outdoor terrains as well as decaying urban/industrial settings. As such, a novel mechanism and controller have been designed to address this need.

Kinematic Design of a 7-DOF Cable-Driven Humanoid Arm: A Solution-In-Nature Approach

G. Yang, W. Lin, S'pore Inst. of Mfg. Tech., *K. M. Shabbir, C. B. Pham, S. H. Yeo*, Nanyang Tech. Univ., Singapore

A solution-in-nature approach has been adopted in the design of a 7-DOF humanoid robotic arm that consists of a 3-DOF shoulder module, a 1-DOF elbow module, and a 3-DOF wrist module. To mimic the driving scheme of the human arm, the three arm modules are all driven by cables which are functionally similar to human muscles. Two critical analysis issues, i.e., displacement analysis and cable-tension analysis are addressed in more details. A closed-form solution is derived for the forward displacement analysis, while an optimization technique is employed for the inverse displacement analysis. An effective cable-tension analysis algorithm is proposed based on convex theory.

16:03—16:21

Analysis and Simulation of a Wheeled-Vehicle with Auxiliary Wheels of Involute-Shape (AWIS)

H. Purnawali, Y. Zhou, M. Xie, Nanyang Tech. Univ., Singapore

This paper introduces an innovative design of Auxiliary Wheel of Involute-Shape (AWIS) as an auxiliary device for a wheeled-vehicle. The AWIS enhances the wheeled-vehicle's adaptability on rugged terrain while not imposing complex-ity in the control. The continuous-variable-radius of the AWIS allows for smoother motion in a sagittal plane. Moreover, the AWIS enables the wheeled-vehicle to traverse obstacles with maximum heights reaching almost five times its base radius. In this paper, the kinematics, statics, and dynamics analyses are performed on the AWIS. The wheeled-vehicle with AWIS traversing obstacles, ascending and descending a flight of staircase is simulated and the results obtained validate the functionality of the AWIS.

A New Humanoid Robot Gait Generation Based on Multiobjective Optimization

G. Capi, M. Yokota, Fukuoka Inst. of Tech., *K. Mitobe*, Yamagata Univ., Japan

Up to now, the optimization algorithms are applied for humanoid robot gait generation, where a single fitness function drives the optimization process. But often, the humanoid robot gait generation problem is subject to several objectives. In order to deal with this problem, in this paper, we propose a new method based on multiobjective evolutionary algorithm. In order to verify the effectiveness of our proposed method, we considered two important conflicting objectives: minimum energy and minimum torque change, simultaneously. The angle trajectories are generated without neglecting the stability of humanoid robot. Results using the Bonten-Maru humanoid robot show a good performance of the proposed method.

16:21—16:39

A Neural Network Based Control System for a Mobile Robot Employing Link Mechanism

M. Sato, K. Ishii, Kyusyu Inst. of Tech., Japan

The transportation using wheels is one of the most popular transportation mechanisms for mobile robots because its energy efficiency is high, the wheel mechanism is simple and the control system is well investigated. Therefore, the wheel type mobile robots are one of the most practical and widespread robots. However, the wheel type mobile robots have the difficulty in the rough terrain movement. In this research, a 6-wheeled mobile robot employing the linkage mechanism, "Zaurus", has been developed to extend maneuverability of wheel type mobile robots. In order to evaluate its maneuverability, the experiments to climb over a bump with twice height of diameter of the robot's wheel have been carried out. Neural Network and PID controllers are introduced as the control system and their performance are compared.

A 3-D Exercise Machine for Upper-Limb Rehabilitation Using ER Actuators with High Safety

J. Furusho, K. Koyanagi, K. Nakanishi, Y. Fujii, Osaka U.
K. Domen, K. Miyakoshi, Hyogo Coll. of Med.
U. Ryu, S. Takenaka, A. Inoue, Asahi Kasei Eng., Japan

We have joined a project managed by 5-year NEDO (New Energy and Industrial Technology Development Organization as a semi--governmental organization under the Ministry of Economy, Trade and Industry of Japan) Project, "Rehabilitation System for the Upper and Lower Limbs", and developed a 3-D exercise machine for upper limbs (EMUL) using ER actuators. New training methods and exercises for upper limbs rehabilitation are made possible by application of robotics and virtual reality technology. This paper deals with the development of EMUL. We also present the development of software for motion...

16:39—16:57

A Gait-Transition Method for a Quadruped Walking Robot

S. Masakado, T. Ishii, K. Ishii, Kyusyu Inst. of Tech., Japan

Legged robots are expected as the attractive tool to transport in various environment such as rough terrain, nuclear reactors, etc. The stability of their motion is one of most important problem and, especially, the gait change should be well considered not to lose the stability. In this paper, we propose a successive gait-transition method with stability secured for a quadruped walking robot. The gait-transitions from a standard gait such as a crawl gait and a rotation gait are investigated to realize the static stable walk. The X-crawl, Y-crawl, O-rotation and their reverse gait are the standard gaits. In the proposed method, the common foot positions, those are the same leg arrangements among standard gaits, are utilized for stable and smooth gait transition. The experimental results show that the proposed gait transition is efficient and stable.

Grasping Unknown Objects Based on 3D Model Reconstruction

B. Wang, L. Jiang, J. Li, H. Cai, Harbin Inst. of Tech., China
H. Liu, Aerospace Center, Germany

Automatic grasping of unknown objects for multifingered hand is a difficult problem because the location and model of the object are unknown and the possible hand configurations are numerous. In this paper, we propose a new strategy for modeling and grasping prior unknown objects based on 3D model reconstruction. The whole system consists of a laser scanner, simulation environment, a robot arm and the HIT/DLR multifingered robot hand. The object to be grasped is scanned by a 3D laser scanner and reconstructed in simulation scene. After different grasping are evaluated within the simulation scenes, an accurate arm and hand configuration can be calculated to command the robot arm and multifigered hand. The experimental results strongly demonstrate the effectiveness of the proposed strategy.

16:57—17:15

Design of Mobile Robots with Wall Climbing Capability

J. Xiao, A. Sadegh, M. Elliott, A. Calle, *A. Persad, H. M. Chiu,* City Coll. of New York, USA

This paper describes the ongoing work and technical achievement in developing novel robots which can achieve quick motion on various wall surfaces and smooth wall-to-wall transitions. Various aspects in mechanical design are discussed in detail, including adhesion mechanism, vacuum chamber seal, locomotion and transition mechanisms. DSP-based control system is also described which enables the robot operating manually and semi-autonomously. Several prototype robots are introduced to verify the design concepts. Future directions to improve the design are elaborated.

Adaptive Neuro-Fuzzy Control Based Development of a Wearable Exoskeleton Leg for Human Walking Power Augmentation

C.-J. Yang, *B. Niu, Y. Chen*, Zhejiang Univ., China

In this paper, a wearable exoskeleton leg conceived and designed to augment human's walking ability is proposed. The ultimate goal of this project is to provide an insight into the methodology of designing and controlling a power assist system, which integrates human's intellect as the central control system for manipulating the wearable anthropomorphic device. The whole process of design, construction and control of a prototype experimental exoskeleton is presented; the feasibility and performance of the novel ANFIS (Adaptive-Network-Based Fuzzy Inference System) based control algorithm are studied followed by the conclusion as well as an outline of anticipated future research.

MD3	Actuators in Mechatronic Systems		Localization and Planning	MD4
	Big Sur 3 (15:45—17:15)		Windjammer 1 (15:45—17:15)	
	Kyi Hwan Park, Korea	CHAIR	Stefano Chiaverini, Italy	
	Zeljko Popovic, USA	CO-CHAIR	Tong-Ying Juang Taiwan	

Inverse Dynamics Control for Series Damper Actuator Based on MR Fluid Damper

W. Zhou, C. M. Chew, G. S. Hong, National U. of Singapore, Singapore

In this paper, inverse dynamics control is investigated to actively control the Magneto Rheological (MR) fluid damper in Series Damper Actuator (SDA), a new type of force control actuator. A modified Bingham model is proposed and proved by comparing with two popular MR fluid models, Bingham model and Bouc-Wen model, in terms of model accuracy and model inverse ability. Inverse dynamics control scheme is developed for MR damper based SDA system and experimental results are also presented to show that high force fidelity is achieved.

15:45—16:03

Feedforward Global/Inertial Sensor Fusion Algorithm for Accurate Global Positioning of a Mobile Robot

K. Lee, KAIST, Korea, *J. Park, O. Khatib*, Stanford U., USA
D. -S. Kwon, Korea Advanced Inst. of Science and Tech., Korea

This paper introduces a coordinate transform method for global/inertial sensor fusion minimizing modification of an existing control program of a mobile robot. Most of GPS/INS sensor fusion algorithms use Kalman filters and modify the INS states by feedback loops. Because the structure of the proposed method has a feedforward filter, the method has an advantage that the user does not want to change an existing control program of mobile robot. The feedback Kalman filter is designed so that the error between global position from GPS and odometry from INS converges to zero. Therefore the coordinate matching between the odometry and measured global position is not necessary in those errors...

Development of an Intelligeny Pneumatic Cylinder and Its Application to Pneumatic Servo Mechanism

K. Sumumori, J. Tanaka, T. Kanda, Okayama Univ., Japan

A new compact pneumatic cylinder with a micro position sensor, named intelligent pneumatic cylinder was developed. It consists of a piston rod with stripe codes and a micro optical MEMS encoder. The stripe codes were fabricated through a selective oxidization process by irradiating with a YAG laser. The cylinder realizes a compact pneumatic position servo system. The servo experimental results were very promising. The piston rod position is easily controlled at any desired position between both ends of the rod stroke. This paper reports also an adaptive servo algorithm which was newly developed for stepping positioning of the intelligent pneumatic cylinder, realizing about 0.3 to 1 mm positioning accuracy without overshooting.

16:03—16:21

Monte Carlo Multi-Robot Localization Based on Grid Cells and Characteristic Particles

J. Liu, K. Yuan, W. Zou, Chinese Acad. of Science, China
Q. Yang, Univ. of Missouri Rolla, USA

In this paper, a Monte Carlo method based approach for multi-robot localization is described. In this approach, grid cells are used to describe the whole particle set which is used in MCL method to estimate the pose of robot. Then, the sizes of the grid cells are adjusted to capture the characteristic particles that can represent the property of all particles. The characteristic particles can be used to estimate the robot's position in its operation space. Because the number of the characteristic particles is much less than that of the total particles, this approach can reduce the computing time greatly. Simulation results are also given to show that this approach can obtain good localization performance

Integrated Control and Power Electronics for an Electro-Mechanical Valve Actuation System

L. A. Mianzo, S. J. Netwon, *Z. Popovic,* Visteon Corp., USA

In an electro-mechanical valve actuated engine, computer-controlled solenoid actuators drive the valves that control airflow into the cylinders, allowing elimination of the camshaft and enabling fully variable valve timing. Control of individual valve timing optimized over all engine operating conditions allows the benefits of variable valve timing to be realized. This paper presents power electronics and control electronics architecture and its control algorithms that achieve precise coil current tracking and regulation of rail voltage which are critical in closed-loop control of the electro-mechanical valve actuator motion. Simulation and experimental results support the design.

16:21—16:39

Range Sensor Data Filtering for Mobile Robot Localization

S. Baek, H. Park, *S. Lee,* Hongik Univ., Korea

Estimating the configuration is one of the key issues for successful mobile robot navigation. Dead-reckoning is simple and fast but it can lead to inaccurate or unreliable estimates. Range sensors are widely used in known environment for localization, but it may not always work due to sensor range limit. Optical flow sensor such as the optical mouse gives accurate relative movement but it requires strict vertical placement. This paper introduces new way of estimating robot configuration by combining the consecutive range sensor data and optical flow information in known environment. Feature extraction from range sensor information and estimation of the relative movement using optical flow sensors are investigated. The proposed method is implemented and tested with a mobile robot.

A Magnetically Controllable Valve to Vary the Resistance of Hydraulic Dampers for Exercise Machines

B. Levins, *I. Gravagne,* Baylor Univ., USA

While the majority of exercise machines use weights, springs or spinning fans to generate motion resistance, a large number of machines also utilize linear fluid damping. Similar to a shock absorber, linear dampers are compact, extremely reliable, and produce "double positive" resistance (resistance to both directions of motion). However, they are difficult to adjust for higher or lower resistance. This paper illustrates a mechanism to vary the resistance of a linear damper, and illustrates with experimental data certain properties of the damper.

16:39—16:57

A Fast Path Planning Algorithm for Piano Mover's Problem on Raster

G. E. Jan, T.-Y. Juang, National Taipei U.
J.-D. Huang, C.-M. Su, C.-Y. Cheng, National Taiwan Ocean U., Taiwan

This article presents the near-optimal path-planning algorithm for piano mover's problem of robot motion among obstacles on raster. Beginning with a top view of a workspace arrangement among obstacles, the so-called free workspace is first obtained by virtually expanding the obstacles. The proposed method adopts virtual obstacle domain and collision avoidance scheme based on the higher geometry maze routing algorithm with all the possible directions to find the near-optimal path from the source position to the destination position. The time complexity of this method is in average or O(RN) for the worst case, where N and R are the numbers of cells in the free workspace and the detection circle with the radius of VRI as its collision-detection domain, ...

Pressure Observer Based Servo Control of Pneumatic Actuators

N. Gulati, E. J. Barth, Vanderbilt Univ., USA

Pneumatic systems are highly non-linear by their nature. Despite their many advantages like reliability, compliance for interaction tasks requiring backdrivability, and high power to weight ratio, the use of such systems is restricted primarily because of its high initial cost. This paper presents the development of a robust observer based controller to eliminate costly pressure sensors and therefore obtain a low cost pneumatic servo system. Experimental results are presented that demonstrate the effectiveness of this pressure observer based controller.

16:57—17:15

Optimization of Emergency Trajectories for Autonomous Vehicles with Respect to Linear Vehicle Dynamics

K. Hirsch, J. Hilgert, W. Lalo, D. Schramm, M. Hiller,
U. Duisburg-Essen, Germany

This paper looks at a trajectory planning strategy for autonomous vehicles. The pre-defined nominal trajectory is analyzed with reference to obstacles modeled from circular safety areas. Based on the results of this analysis, an emergency trajectory is calculated by using the method of elastic bands which provides flexible trajectories with minimal changes of curvature and therefore good driveability. In a second step, the dynamic behavior of the vehicle is evaluated using the bicycle model along with a first approximation of the steering angle along the trajectory. Then the vehicle trajectory calculated from this steering angle is improved by iterating the steering angle based on …

MD5

Micro Robotics, Assembly, and Synthesis

Windjammer 2-3 (15:45—17:15)

Metin Sitti, USA — CHAIR

Yi Su, Singapore — CO-CHAIR

MEMO

6 DOF Dexterous Microgripper for Inspection of Microparts — 15:45—16:03

Q. Zhou, P. Korhonen, B. Chang, V. Sariola, Helsinki Univ. of Tech., Finland

This paper presents a novel 6 DOF (degree-of-freedom) piezoelectric micro gripping/handling system for automatic dexterous manipulation and inspection of micro optoelectronic components. The purpose of the system is to pick-and-place and aligns microparts having size of 300 to 400 µm square. The alignment task includes both translational alignment for field-of-view and focusing, and rotational alignment for uniform focusing. All six actuation axes are controlled based on strain gauge sensor feedback. A network-based control system is used for automatic control of the gripper. The control system includes three hierarchical layers: actuator control layer, motion planning layer, and mission layer. Visual servoing is applied in automatic handling. The performance of the system is demonstrated in a fully automated inspection task.

First Research Achievements of the Project ASSEMIC on Microhandling and -Assembly Technologies — 16:03—16:21

A. Almansa, S. C Bou, ARC Seibersdorf Res. GmbH, Austria

Mechatronic competences represent a strong component in Microsystem Technologies, but very especially in Microhandling and –assembly, a field with challenging requirements. The Research and Training Network "Advanced Methods and Tools for Handling and Assembly in Microtechnology" (ASSEMIC) addresses this research field at a European scale. Topics as design and development of microgrippers, intelligent micromanipulation methods and microassembly technologies for industrial production are dealt with by the 14 institutions participating in this project.

Electrodeposition Combined with Microjet Flow: Fabrication of Metal Microtubes — 16:21—16:39

P. Loew, N. Takama, B. Kim, Univ. of Tokyo, Japan

A concept of using electrodeposition and microfluidic flow for the fabrication of metal microtubes on a Silicon wafer is presented. Two subsequent electrodeposition steps were used. At first, Copper was deposited on a microporous Si membrane structure. By flowing water through the holes of the membrane during deposition, the holes avoided being clogged and were replicated into the Copper layer. Gold was deposited on the inner walls of the Copper layer holes. Through selective etching of the Copper, free-standing Gold microtubes were left. This method could be useful in fabricating devices for cell handling and Lab-on-a-chip.

A New Endoscopic Microcapsule Robot Using Beetle Inspired Microfibrillar Adhesives — 16:39—16:57

E. Cheung, M. E. Karagozler, Carnegie Mellon U., *S. Park, B. Kim*, Korea Inst. of Science & Tech., Korea, *M. Sitti*, Carnegie Mellon U., USA

The diagnosis of gastrointestinal diseases within the small intestine has been greatly advanced with the introduction of the endoscopic microcapsule in recent years. In an effort to increase its reliability and expand its functionality, a mechanism for stopping and locomoting the capsule within the digestive tract is proposed in this paper. This mechanism, actuated by shape memory alloy wires, utilizes a synthetic microfibrillar adhesive similar to the attachment mechanisms employed by beetles. This fibrillar attachment mechanism is a combination of molecular adhesion caused by van der Waals forces and liquid adhesion caused by capillary forces….

Development of Pneumatic End Effector for Micro Robotic Manipulators — 16:57—17:15

U. C. Wejinya, Y. Shen, N. Xi, E. Winder, Michigan State Univ., USA

In this paper, a micro pneumatic end-effector for micromanipulation and microassembly with in-situ PVDF sensing is designed and calibrated. The micro pneumatic end-effector system consists of a DC micro-diaphragm pump and compressor, two regions of flexible latex tubes with different parameters and different function such as microtool and air channel. Effectively controlling the suction force and pressure are critical for the performance of the micro-pneumatic end-effector for micromanipulation and microassembly. The force sensing model was developed for the pneumatic end-effector system. An effective calibration method is proposed and its results verify the behavior of the developed pneumatic end-effector system.

TA1	Mechatronics in Medical Applications		Modeling and Design of Mechatonic Systems	TA2
	Big Sur 1 (09:30—10:42)		Big Sur 2 (09:30—10:42)	
	Masayoshi Wada, Japan	CHAIR	I-Ming Chen, Singapore	
	Michael Bailey-Van Kuren, USA	CO-CHAIR	Marcelo H. Ang, Singapore	

Control of Model-Based Wearable Anti-Gravity Muscles Support System for Standing up Motion

T. Nakamura, K. Saito, Z. D. Wang, K. Kosuge, Tohoku Univ., Japan

As an apprication of real world robotics, we have focused on developing a wearable daily activities support system for physically weak person. For controlling a wearable human support device, we have proposed novel control algorithms. In these algorithms, joint support moments are calculated based on human body dynamics. In this paper to validate the usefulness of proposed system, the standing up motion, one of the hardest activities of daily life is analyzed and the usefulness of proposed method is discussed. Experimental results show the validity of the system.

09:30—09:48

Integrated Design for a Mechatronic Feed Drive System of Machine Tools

C. -Y. Chen, C. -C. Cheng, National Sun Yat-Sen Univ., Taiwan

The goal of this research is to develop a design optimization methodology for mechatronic modules of machine tools by treating all important characteristics from all involved engineering domains in one single process. In this study, a mechatronic system of machine tools was broken into a structure and a control two-level system. In the first stage for the structure design process, the Pro/E was used to build up the 3D models and the AnSys was employed to design the mechanical structure and select optimal components for the machine tool. Next, in the control design process, a common controller type was designed by MATLAB in this stage. Then, three important parameters were established for the machine tool design to achieve the overall system performance.

Mechatronic Applications in Pediatric Therapy Devices

M. Bailey-Van Kuren, D. Scarborough, Miami Univ., USA

Mechatronic devices can provide solutions in pediatric physical and occupational therapy that improve the level of care, improve patient comfort, and explore new therapy methods. A family of mechatronic devices based on thin film sensors is discussed. Thin film force sensitive resistors (FSR) provide a low cost component for force based inputs. Pediatric applications in manual muscle testing, walking therapy, and feeding therapy are presented. Design considerations characterizing the needs of each pediatric device are summarized. System components including the actuators, sensors and controllers are presented.

09:48—10:06

Design of Intelligent Mechatronical Systems with Modifiable Behaviors

M. Koch, Univ. of Paderborn, *C. Rust*, ORGA

B. Kleinjohann, Univ. of Paderborn/Siemens, Germany

We present and extend an approach for the integration of Reinforcement Learning methods into Petri net based specifications of autonomous behaviors. The work aims at the design of autonomous mechatronical systems with modifiable adaptive behavior and our extension handles the required modifiability. In order to combine Petri nets and learning methods, we modeled Q-Learning - a variant of Reinforcement Learning - with high-level Petri nets. The result can be integrated into Petri net models of autonomous mechatronical systems. For an evaluation of our approach, we have implemented a realistic application example. It has been evaluated by simulation as well as on a physical system.

An Omnidirectional 4WD Mobile Platform for Wheelchair Applications

M. Wada, Saitama Inst. of Tech., Japan

In this paper, a new type of omnidirectional mobile platform with four-wheel drive (4WD) mechanism is presented. The mobile platform includes a pair of normal wheels on the rear side of the platform and a pair of omni-wheels on the front side. The two drive motors are coordinated by the omnidirectional control to translate the center of the chair in an arbitrary direction while chair orientation is controlled by the third motor individually. In the paper, kinematics and statics of the 4WD mechanism are analyzed and an omnidirectional control method is developed. The omnidirectional motions of the proposed 4WD drive system are tested by the computer simulations.

10:06—10:24

A New Continuously Differentiable Friction Model for Control Systems Design

C. Makkar, W. Dixon, W. Sawyer, G. Hu, Univ. of Florida, USA

For high-performance engineering systems, model-based controllers are typically required to accommodate for the system nonlinearities. Unfortunately, developing accurate models for friction has been historically challenging. Typical models are either discontinuous and many other models are only piecewise continuous. Motivated by the fact that discontinuous and piecewise continuous friction models are problematic for the development of high-performance continuous controllers, a new model for friction is proposed in this paper. This simple continuously differentiable model represents a foundation that captures the major effects reported and discussed in friction modeling and experimentation.

Embedded FPGA-Based Control of the HIT/DLR Hand

Y. Liu, M. Jin, R. Wei, H. Cai, Harbin Inst. of Tech., China

H Liu, N. Seitz, R. Gruber, G. Hirzinger, DLR, Germany

In this paper, we developed a performanceenhanced, standalone dexterous robot hand with effective mechanical structure and lightweight control hardware. In the context, the paper shows the design methodology of HIT/DLR dexterous robot hand II controller using FPGA (Field Programmable Gate Array). Lower level controller is implemented in an FPGA and higher level controller is implemented in a DSP. Instead of a conventional architecture,a FPGA-based soft processor core is utilized. It includes a set of custom peripheral cores, such as data collection, brushless DC motors control and communication with palm's FPGA by Point-to-Point Serial Communication (PPSeCo). The experiments results clearly illustrate the high performance of the control system we presented in the paper.

10:24—10:42

A Unified Model for Design and VLSI Implementation of Robotic Perceptive Controller

Y. Sun, N. Xi, Michigan State Univ. *W. Sheng*, Kettering Univ., USA

In this paper, a formal hybrid model is used for both the controller design and hardware description. The model can describe the control functions and the high level behavior of the robotic system. The high level structural description of the controller model guarantees the synthesizability of the control system. A hybrid simulation system is proposed to test the hybrid controller design and implementation. The hybrid simulation results have verified that the hybrid system model can be used for VLSI implementation, and the integrated system is synthesizable.

TA3	Design of Parallel Mechanisms I		Sensor System Integration	TA4
	Big Sur 3 (09:30–10:42)		Windjammer 1 (09:30–10:42)	
	Koichi Osuka, Japan	CHAIR	Imad Elhajj, USA	
	Guilin Yang, Singapore	CO-CHAIR	Kourosh Parsa, Canada	

09:30–09:48

Dynamic Analysis of Cable-Driven Parallel Mechanisms

C. B. Pham, Nanyang Tech. Univ., *G. Yang*, Singapore Inst. of Manuf. Tech., *S. H. Yeo*, Nanyang Tech. Univ., Singapore

A Cable-Driven Parallel Mechanism (CDPM) possesses a number of promising advantages over the conventional rigid-link mechanisms, such as simple and light-weight mechanical structure, high-loading capacity, and large workspace. However, the formulations and results obtained for the rigid-link mechanisms cannot be directly applied to CDPMs due to the unilateral property of cables. For a CDPM, dynamic formulation is only valid as actuators exert positive torques. In this paper, cable winding method is studied as it improves the whole dynamic performance of the system. This is followed by dynamic formulation. A generic approach based on dimension reduction technique is proposed to check the existence of positive torques.

Motion Planning in Robotized Sensor Networks for Aircraft Rivet Inspection

W. Sheng, Kettering Univ., *Y. Shen, N. Xi*, Michigan State Univ., USA

This paper proposes a new robotized mobile sensor network platform to conduct aircraft rivet inspection and addresses the motion planning problem involved. Due to the specific movement characteristics of the mobile robot, the path, or the rivet sequence, should enable each mobile robot to realize the localization-and-reposition process. In this paper, we propose a new algorithm to extend our previous single robot path planning algorithm into the multiple robots version. This algorithm first decomposes the overall rivet set into multiple disjoint subsets based on a graph partitioning algorithm. Then for each subset, we apply our Find-Crawler-TSP algorithm to generate the path. Simulation results validate the proposed algorithm.

09:48–10:06

A 3-DOF Flexure-Based Fixture for Passive Assembly of Optical Switches

W. Chen, W. Lin, Singapore Inst. of Manuf. Tech., *K. H. Low*, Nanyang Tech. Univ., *G. Yang*, Singapore Inst. of Manuf. Tech., Singapore

This paper presents the design of a planar compliant fixture for optical switch assembly to automatically accommodate the uncontrollable assembly errors. The fixture comprises a platform movable in x-y-$_z$; and three flexure-based supporting legs. Compliance performance is mainly concerned in the design. A closed-form formulation is developed to map the stiffness in the joints space into Cartesian space for generic 3-legged planar platforms. Based on the stiffness requirement, the structure and the configuration of the legs are synthesized and designed. Experimental results showed that the performance of the optical switch assembly system is improved significantly after adopting the fixture.

Design and Mechatronic Implementation of an Accelerometer-Based, Kinematically Redundant Inertial Measurement Unit

K. Parsa, Canadian Space Agency, Canada
T. A. Lasky, B. Ravani, U. of California, Davis, USA

This paper discusses the design, calibration, and simulation of a redundant inertial measurement unit based solely on accelerometers. The unit comprises twelve sensors, two on each face of a cube. The sensor locations and directions are determined so as to locally optimize the numerical conditioning of the governing kinematic equations. The orientational installation errors are identified by off-line iterative processing of the gravitational acceleration measurements made at a number of known orientations. Furthermore, a procedure is developed through which the acceleration measurements can be used to directly determine the body angular velocity; this results in a major accuracy ...

10:06–10:24

Proposal of a New Forward Kinematics Calculating Method and Control Law for Parallel Link Manipulators

K. Osuka, Kobe Univ., *H. Kubo*, Kawasaki Heavy Industries,
Y. Minase, Kyoto Univ., *K. Ueshima*, *Y. Nakamura,* Murata Machinery, Japan

In this paper, we propose a novel solving method of forward kinematics problem for PLMs and construct a task coordinated feedback control which used the character of Jacobian and made calculation easy. Then we prove the stability of this control system and verify the validity by the simulation and experiment.

Sensor Network Assisted Teleoperation

J. Gorski, I. Elhajj, Oakland Univ., USA

Rapid advances in the field of sensing and sensor networks are opening the door to many new possibilities. This paper presents work related to interfacing a robot being controlled remotely via the Internet with a sensor network. The sensor network measurements are fed back to the operator and rendered in the form of a haptic force. This provides the operator with information regarding the environment and thus more efficient and safe operation. The challenge is to efficiently fuse the measurements from the different nodes and convey the result to the operator in an intuitive form. A centralized approach and a distributed approach for the fusion of sensed measurements are presented. In addition, experimental results are provided to highlight the concepts developed.

10:24–10:42

Design, Modeling and Advanced Control of the Innovative Parallel Manipulator PaLiDA

B. Denkena, B. Heimann, H. Abdellatif, C. Holz, Univ. of Hannover, Germany

In this paper, design, actuation concept and the advanced control of the parallel manipulator PaLiDA are presented. Commercial direct linear drives are integrated into newly designed struts variable in length. The strut's arrangement is carried out basing on the optimization of the workspace and stiffness. A highly efficient approach for the calculation of the dynamics is presented. It is characterized by the uniform consideration of rigid-body and friction dynamics. The implementation of feedforward control with additional partial decoupling of actuator dynamics is shown. Experimental results demonstrate the quality of the achieved control in the range of high-speed manipulation and machining.

Development of the Balloon-Cable Driven Robot for Information Collection from Sky and Proposal of the Search Strategy at a Major Disaster

F. Takemura, Int'l Res. System Inst., *M. Enomoto, T. Tanaka, K. Denou*, Kobe U., *Y. Kobayashi*, *S. Tadokoro*, Tohoku U. Japan

At large-scale urban earthquake disaster, the human search and the information collection are the most important process of rescue activities. This research develops the balloon-cable driven robot for information acquisition from sky at crushed structures at landslide caused by huge earthquake. The balloon, which hangs up several sensors (Sensor Unit, SU), uses ``a natural shape balloon''. Three cables are connected with SU, and the balloon with sensors is driven by expansion and contraction of the cables length. Moreover, we propose the human search system by electromagnetic waves. Recently, a lot of people have cellphones or mobile devices. Our proposing search system is the ...

TA5

Neural Control in Mechatronics

Windjammer 2-3 (09:30–10:42)

Nader Sadegh, USA — CHAIR

Lilong Cai, Hong Kong — CO-CHAIR

Superficial Pain Model Using ANNs and Its Application to Robot Control 09:30–09:48

N. Matsunaga, A. Kuroki, S. Kawaji, Kumamoto Univ., Japan

In the coexistence circumstance with humans and robots, sensory and emotional feeling of human should be considered when the robots interact to human. A typical unpleasant feeling at interaction is "pain". It is difficult to separate the robots from human in the sense of time or place in coexisting environment unlike factory automation design. Thus a new concept of separation in the sense of safety is required. One approach is to design the controller based on the pain that is subjective of human. In this paper, artificial superficial pain model (ASPM) caused by impact is proposed. This ASPM model consists of mechanical pain model, skin model and gate control by artificial neural networks (ANNs). The proposed ASPM is applied to robot control and evaluated.

Tracking Control of Nonlinear Systems Using Fourier Neural Network 09:48–10:06

W. Zuo, L. Cai, Hong Kong Univ. of Science and Tech., Hong Kong

A Fourier neural network (FNN) based control scheme is presented in this paper for tracking control of a class of unknown nonlinear systems. The FNN employs orthogonal complex Fourier exponentials as the basis functions, and therefore the FNN has a clear physical meaning and the network topology is easily determined. Due to the orthogonality of the basis functions, the FNN has a fast convergent speed and can avoid local minimum. Taking advantage of the FNN, the proposed FNN controller requires no priori knowledge of the system and is suitable for real time control. The stability analysis of the closed-loop system is based on the Lyapunov theory. Experimental results on a gearbox are given to show the effectiveness of the proposed controller.

The Heart Disease Diagnosing System Based on Force Sensitive Chair's Measurement, Biorthogonal Wavelets and Neural Networks 10:06–10:24

A. Akhbardeh, S. Junnila, M. Koivuluoma, T. Koivistoinen, A. Värri, Tampere Univ. of Tech., Finland

The Heart Disease Diagnosing (HDD) system consists of a movement sensitive EMFI-film sensor installed under the upholstery of a chair. Whilst a man rests on the chair, this sensor produces a signal containing components reflective of cardiac-Ballistocardiogram (BCG), respiratory, and body movement related motion. This paper describes briefly our developed HDD system and especially a combined intelligent signal processing method to detect, extract features, and finally cluster BCG cycles. The system is designed to assist medical doctors in diagnosis. It uses high resolution Biorthogonal wavelet transform to extract essential BCG features and then clusters them using Artificial Neural Networks…

PID Neural Network Control of SUT Building Energy Management System 10:24–10:42

M. Fardadi, A. Selk Ghafari, S. K. Hannani, Sharif Univ. of Tech., Iran

PID Neural Network controller design for Sharif University of Technology (SUT) Building Energy Management System (BEMS) is addressed in this paper. The most important characteristics of process systems are time delay with model uncertainties. Artificial neural networks can perform adaptive controller properties through learning processes. PID neural network has the advantages of both conventional PID controllers and the neural structure. Simulation results using Modified Hooke-Jeeves Optimization Method show that this controller has short convergence time and quick learning speed and the performance of the closed loop system is very good.

MEMO

TB1	Aerial and Underwater Robots		Dynamic Modeling of Robotic Manipulators	TB2
	Big Sur 1 (11:00—12:30)		Big Sur 2 (11:00—12:30)	
	Paul Y. Oh, USA	CHAIR	Masayoshi Tomizuka, USA	
	Ruggero Frezza, Italy	CO-CHAIR	Kok-Meng Lee, USA	

Aircraft Maneuver Regulation: A Receding Horizon Backstepping Approach

G. Notarstefano, R. Frezza, Univ. di Padova, Italy

Coordinated flight is a nonholonomic constraint that implies no sideslip of an aircraft. The equations of motion in coordinated flight are kinematically reducible. This property simplifies the maneuver regulation problem because under such assumption it is possible to write a lateral controller for the transverse dynamics independent of velocity. Assuming coordinated flight, the maneuver regulator consists of a model predictive controller based on the kinematic model. Since, in reality the coordinated flight assumption is seldom satisfied, the kinematic control action is back-stepped into dynamics to compute the actuation of the control surfaces. The proposed control law is tested on a multi-body SW model of an aircraft on various maneuvers, including some aggressive ones.

11:00—11:18

Modelling and Control of a 2-DOF Planar Parallel Manipulator for Semiconductor Packaging Systems

J. W. F. Cheung, ASM Assembly Automation Ltd. & U. of Hong Kong
Y. S. Hung, U. of Hong Kong, Hong Kong

A novel direct-drive planar parallel manipulator for semiconductor packaging systems is presented. High precision kinematics design, significant reduction on moving mass and driving power of the actuators over traditional XY motion stages are the benefits of the proposed manipulator. The mathematical model is obtained using Newton-Euler method and model-based control design approach is employed to design the PID computed-torque controller. Experimental results demonstrate that the proposed manipulator has significant improvements on motion performance in terms of positioning accuracy, settling time and stability when compared with traditional XY stages….

A MAV That Flies Like an Airplane and Hovers Like a Helicopter

W. E. Green, P. Y. Oh, Drexel Univ., USA

Near-Earth environments, such as forests, caves, tunnels, and urban structures make reconnaissance, surveillance and search-and-rescue missions difficult and dangerous to accomplish. Micro-Air-Vehicles (MAVs), equipped with wireless cameras, can assist in such missions by providing real-time situational awareness. This paper describes an additional flight modality enabling fixed-wing MAVs to supplement existing endurance superiority with hovering capabilities. This secondary flight mode can also be used to avoid imminent collisions by quickly transitioning from cruise to hover flight. A sensor suite which will allow for autonomous hovering by regulating the aircraft's yaw, pitch and roll angles is also described.

11:18—11:36

Limit Cycles Due to Friction Forces in Flexible Joint Mechanisms

J. Soo, M. Tomizuka, Univ. of California at Berkeley, USA

The paper investigates the limit cycle phenomena in flexible joint mechanisms due to motor side Coulomb friction and load side friction with more emphasis on the latter. Two friction forces are studied separately as independent sources of limit cycles. Controller instability is considered as a sufficient condition for a limit cycle to appear. Simulation and experimental results are presented to confirm analysis.

Exploring Search-And-Rescue in Near-Earth Environments for Aerial Robots

K. Sevcik, W. E. Green, P. Y. Oh, Drexel Univ., USA

Homeland security missions executed in near-Earth environments are often time consuming, labor intensive and possibly dangerous. Aerial robots performing tasks such as bomb detection, search-and-rescue and reconnaissance could be used to conserve resources and minimize risk to personnel. Flying in environments which are heavily populated with obstacles yields many challenges. Little data exists to guide the design of vehicles and sensor suites operating in these environments. This paper explores the challenges encountered implementing several different sensing technologies in near-Earth environments. The results of applying these technologies to control a robotic blimp are presented to direct future work.

11:36—11:54

Dynamic Model of a Compliant Link with Large Deflection and Shear Deformation

C.-C. Lan, K.-M. Lee,Georgia Inst. of Tech., USA

The dynamic model for links in mechanisms has often based on small deflection theory without considering shear deformation. For light-weight links or high-precision elements, it is necessary to capture the deflection caused by shear forces. A complete dynamic model is presented to characterize the compliant link motion capable of large deflection with shear deformation. We derive the governing equations from Hamilton's principle along with the essential geometric constraints that relate deformation and coordinate variables, and solve them using a semi-discrete method based on the Newmark scheme and shooting method that avoids the problem of shear locking that occurs when using finite elemnet method. We expect that this model will serve as a basis for analyzing general compliant multi-link mechanisms.

Dynamic Positioning of AUVs in Shallow Water Environment: Observer and Controller Design

S. Liu,, D. Wang, E. K. Poh, Y. Wang, Nanyang Tech. U., Singapore

This paper presents a globally asymptotically stabilizing (GAS) output feedback controller for dynamic positioning (DP) of Autonomous Underwater Vehicles (AUVs) operating in shallow water area. An observer is used to estimate the wave velocity, wave motion displacement, vehicle's velocity, and noise free position and rotation angle information which are used in the output feedback controller. A separation principle which holds for AUV model in this paper is used for stability proof of the closed-loop system. The separation principle is based on recent results of cascaded nonlinear systems and Lyapunov stability theory. The closed-loop system has been illustrated using an AUV and the simulation shows the good performance of the observer and the controller.

11:54—12:12

Conceptual Design, Structural Analysis and Performance Evaluation of a Novel Planar Parallel Robot

Q. Ding, L. Sun, H. Hu, Y. Wang, Harbin Inst. of Tech., China

This paper reports conceptual design and structural analysis of a novel planar parallel robot including parallelogram packages. The appropriate natural frequencies of robot throughout the whole workspace are predicted by FEA dynamic simulation, in which both links' and joints' flexibility is considered. And four main factors to determine natural frequency of the robot, payload, flexibility of joints, and cross section of links and pose of robot, are analyzed. Extensive structural vibration experiments with the completed manipulator confirm the simulation results. Performance evaluation experiments prove the robot's performance under a 1D-2D fuzzy self-tuning PI controller, the settling time is less than 100 milliseconds under normal working cycle and the peak acceleration reaches 5g.

A Robust Nonlinear Controller for Underwater Vehicle-Manipulator Systems

B. Xu, Tulane U., USA, *S. Abe*, Ritsumeikan U.; *N. Sakagami*, Tokai U., Japan
S. R. Pandian, Tulane U., USA

In this paper, a robust nonlinear controller is proposed for trajectory tracking of underwater vehicle- manipulator systems (UVMS). The controller is non-adaptive and of sliding mode type, and is designed based on the decentralized form of the dynamics of UVMS. It has the advantages of simplicity, robustness, precise performance, and ease of implementation. In order to demonstrate the effectiveness of the controller, several simulations using a five degrees of freedom UVMS are conducted. The results show that the proposed controller provides high performance of trajectory tracking in the presence of uncertainties about the dynamics and hydrodynamic disturbances.

12:12—12:30

Implementation of a Fully Automated Greenhouse Using SCADA Tool Like LabVIEW

S. Bhutada, S. Shetty, R. Malye, V. Sharma, S. Menon, R. Ramamoorthy, VES Inst. of Tech. Mumbai Univ., India

The paper discusses the automation of a free-standing greenhouse using Supervisory Control & Data Acquisition (SCADA) system. The end product is expected to give the farmer or end-user a kiosk type approach. Entire greenhouse operation will be governed and monitored through this kiosk. This approach is fairly novel considering the unified system design and the SCADA platform, NI LabVIEW 7.1. The design uses efficient sensing technologies enabling the controller to predict and act on situations for perfectly controlled climatic conditions. It also performs redundant and time driven tasks when programmed, thus saving manpower. It uses scientific agricultural methods to obtain...

TB3	Design of Parallel Mechanisms II		Identification and Estimation in Mechatronics	TB4
	Big Sur 3 (11:00—12:30)		Windjammer 1 (11:00—12:30)	
	Max Meng, Hong Kong	CHAIR	Bin Yao, USA	
		CO-CHAIR	Wei Wei Wang, Canada	

RoboTenis: Design, Dynamic Modeling and Preliminary Control

L. Angel, J. M. Sebastian, R. Saltaren, R. Aracil, R. Gutierrez, Univ. Pol. de Madrid, Spain

The accomplishment of robotic tasks involving dynamical environments requires lightweight yet stiff structures, actuators allowing for high acceleration and high speed, fast sensor signal processing, and sophisticated control schemes which take into account the highly nonlinear robot dynamics. As a tool for the investigation of these issues we present the RoboTenis system. This system proposes the design and construction of a high-speed parallel robot that will perform complex tasks aided by a vision system. As a specialized application to demonstrate its speed and versatility we intend the robot to play table tennis. In this paper we present the design of the parallel robot, the dynamic modeling and the first control experiences. The results prove that the system is able of performing the desired …

11:00—11:18

Time-Effective Direct Dynamics Identification of Parallel Manipulators for Model-Based Feedforward Control

H. Abdellatif, B. Heimann, C. Holz, Univ. of Hannover, Germany

Model-based control of robotic manipulators necessitates accurately parameterized models. This issue is especially important for complex and coupled mechanisms like parallel manipulators. This paper provides a methodology that permits the estimation of model parameters in a time-inexpensive manner. Due to the limited workspace, a bounded and periodic excitation trajectory is advantageous. Only one measurement procedure is necessary for accurate identification, which is carried out by means of the Markov estimator. Rigid-body and friction models are identified and integrated in a feedforward control. The success, accuracy and robustness of the proposed methodology are substantiated with a multitude of experimental results.

Parameter Synthesis for Parallel Kinematic Machines from Given Process Requirements

A. Pott, U. of Duisburg-Essen, *T. Boye*, U. of Stuttgart
M. Hiller, U. of Duisburg-Essen, Germany

Parallel kinematic machines are complex systems which kinematic properties vary in the workspace. Normally the machine's task implies requirements e.g. size of the workspace and dexterity that must be taken into account for the design of the machine. We demonstrate geometrical parameter synthesis based on interval analysis for the parallel kinematic machine with constant leg length Linapod. The proposed algorithm enables us to determine all parameter sets that fulfill given process requirements like size of the orientation workspace and a given upper bound on the kinematic dexterity. The use of interval analysis guarantees the validity of the results and is robust against numerical ….

11:18—11:36

Non-Linear Pressure Observer Design for Pneumatic Actuators

N. Gulati, E. J. Barth, Vanderbilt Univ., USA

Robust precision dynamic control of pneumatic systems requires model-based control techniques. These controllers require full state knowledge of the system. For measuring two of the states, two expensive pressure sensors per axis are required and hence it makes the system economically non-competitive with most electromagnetic types of actuation. This paper presents the development of two Lyapunov-based pressure observers for the pneumatic actuator system. The first method shows that an energy-based stable pressure observer can be developed with the state equations. The other method incorporates the output error to control the convergence of the observed pressures. Simulation and experimental results are presented that demonstrate and validate effectiveness of the proposed observers.

Mechatronic Design of a Parallel Manipulator for Milling

M. Petko, G. Karpiel, AGH Univ. of Science and Tech., Poland

The paper presents the process of development of a parallel manipulators for milling, and justifies why mechatronic approach can lead to successes. The resulting construction is a novel, versatile 3-RRPRR (Revolute-Revolute-Prismatic-Revolute-Revolute joints), fully-parallel manipulator with three translational degrees of freedom, characterizing in comparatively high payload capacity, large workspace and high attainable accelerations. The construction of the manipulator is shown, with analysis of its kinematics and dynamics. An initial controller for identification purposes is proposed, simulated and experimentally investigated. Finally, the conclusions are presented.

11:36—11:54

Automated Modelling of Cartridge Valve Flow Mapping

S. Liu, B. Yao, Purdue Univ., USA

Proportional poppet-type cartridge valves are the key elements of the energy saving programmable valves. Unlike costly conventional four-way valves, the cartridge valve has simple structure and is easy to manufacture, but its complicated mathematical model makes the controller design and implementation rather difficult. This paper focuses on the automated modelling of the cartridge valve flow mapping without using any extra sensors and removing the valves from the system. The estimation of the flow mapping is based on the pressure dynamics in the hydraulic cylinder with consideration of some unknown parameters like effective bulk modulus of fluid. Experimental results are obtained to illustrate the effectiveness and practicality of the proposed novel automated modelling method.

Design of a 6-DOF Compliant Manipulator Based on Serial-Parallel Architecture

D. Chao, G. Zong, R. Liu, Beihang Univ., China

A novel dexterous 6DOF manipulator serially connected by two compliant parallel stages is presented in this paper. The upper stage is a 3-RPS mechanism and the lower one is a 3-RRR mechanism. In virtue of the method of the physical model of the solution space, optimal design of the lower stage has been accomplished. Then, the calibration of the lower stage is undergoing by means of an ultra-precision vision system. The experiment shows that the lower stage possesses workspace of 120μm × 130μm × 18mrad with the resolution of 50nm, 50nm, 18arcsec, respectively. This manipulator is to be used as a fiber optics aligner.

11:54—12:12

Towards an Ubiquitous Wireless Digital Writing Instrument Using MEMS Motion Sensing Technology

G. Zhang, G. Shi, Y. Luo, H. Wong, W. J. Li, P. H. W. Leong, Chinese U. of Hong Kong, *M. Y. Wong*, DAKA Development, Hong Kong

MEMS accelerometers and gyros is developed for real-time recognition of human hand motions, with appropriate filtering and transformation algorithms, becomes a Digital Writing System that can be used to record handwriting on any surface. The overall size of our μIMU is less than 25*70*20 mm, including the micro sensors, processor, and wireless interface. We present our progress on using this μIMU based on Kalman filtering algorithm, which has allowed the system to successfully transform hand motions into recognizable and recordable English characters. Our goal is to implement this system to a digital hand-writing instrument with PC and mobile devices interface.

Robotic Pet Based Interactive Home Healthcare System

Q. Ling, Chinese Acad. of Sciences, *M. Meng,* Chinese Univ. of Hong Kong, *M. Tao,* Chinese Acad. of Science, China

Using entertaining robotic pets in home healthcare monitoring system is featured in this paper. The structure, features and control system of this home healthcare system are presented. Hybrid evolutionary control architecture with the virtues of both AI-based and behavior-based control architecture is proposed. The designed architecture endows the robot with the ability of learning, adaptation, quick reactive speed and rationality, and the ability of accomplishing given tasks. The design of home healthcare system makes sure that the robotic pet reliably accomplishes the vital physiological data collection, data transmission and healthcare tasks with strong situation adaptability, low costs and high robustness.

12:12—12:30

Genetic Algorithm Based System Identification and PID Tuning for Optimum Adaptive Control

D. Pereira, J. Pinto, Federal Univ. of Mato Grosso do Sul, Brazil

In this paper the Genetic Algorithm optimization technique, is successfully applied in system identification and PID tuning for optimum adaptive control. In the proposed approach, two independent Genetic Algorithms were used sequentially. The first one is used for system model identification and the second one for PID controller tuning. Once the plant model was identified the parameters found are used to tune the PID controller. The performance of the system for a first order plant whose dynamic characteristics changes in time are presented. The results show the cascaded Genetic Algorithms system capability to adapt the controller to dynamic plant characteristics changes in order to increase system performance and reliability.

TB5

Fuzzy Control Applications

Windjammer 2-3 (11:00—12:30)

Jizhong Xiao, USA — CHAIR

Luc Gaudiller, France — CO-CHAIR

MEMO

Improvement of Potential Energy Exchange Using Nonlinear Control

F. Matichard, L. Gaudiller, INSA de Lyon - Inst. National des Sciences Appliquées, France

This study proposes a nonlinear control method for improving the energy exchange between a structure and actuators. This paper deals with the improvement of stiffness actions for which emulated strain energy is accumulated by actuators and then released to the structure. A fuzzy modal control design aimed at improving this emulated potential energy control is proposed. Energy released to the structure is then minimized and transient responses are reduced. Its efficiency is first analyzed on the control of a single mode of the structure and a decrease of maximum control voltage is obtained. Then the method is applied to the modal control of a smart structure actuated by a PZT component.

11:00—11:18

Nonlinear Approach for Control of Mechanical Coupling Effects and Smart Structures of Limited Power

L. Gaudiller, F. Matichard, INSA de Lyon - Inst. National des Sciences Appliquées, France

Smart structures are often constrained on voltage and power. Moreover, when subjected to rigid body displacements, mechanical couplings cause vibrations. The aim of this work is, on the one hand, to describe a control design that reduces vibrations in flexible structures caused by rigid body modes and, on the other hand, to optimize the mechanical work of actuators controlling flexible modes. The nonlinear method proposed highly improves the control of linear or linearized structures. The fuzzy design implemented to carry out these independent nonlinear approaches is described after which the method is used to control a mono-articulated smart structure. Simulation results show successive ...

11:18—11:36

High Precision Fuzzy Impedance Control of Free-Form Surfaces Polishing Robotic Arm Based on Position Control

Y. Chen, J. Zhao, B. Wang, S. Han, Jilin Univ., China

In this paper, a novel impedance control method for high precision fuzzy controller with self adjustment quantitative factor is presented. This method can not only realize the real-time control by adjusting impedance parameters, but also enhance the stability and dynamic characteristics of the system. We have demonstrated this strategy is feasible and effective based on the simulation researches of free-form surfaces polishing robotic arm.

11:36—11:54

The Hybrid SOF-PID Controller for a MIMO Nonlinear System

T.-Y. Choi, K.-H Seo, J.-H. Shin, J.-J Lee, Korea Adv. Inst. of Science and Tech., Korea

The application of the hybrid self-organizing fuzzy PID(SOF-PID)controller to a multi input multi output(MIMO) nonlinear biped robot is studied in this paper. The self-organizing-fuzzy PID controller was initially studied by H. B. Kazemian but actually his self-organizing-fuzzy PID controller has limits. The supervisory of the self-organizing-fuzzy PID controller can adjust only a kinds of parameters. In his study he has only tuned proportional gain and other parameters, differential and integral, were set by Ziegler-Nichols tuning method. Ziegler-Nichols tuning method is just kind of table based tuning method and there is no guarantee to sure generated parameter's fitness for current system. So in here the hybrid self-organizing-fuzzy PID controller is introduced.

11:54—12:12

Motion Mode Control in Double Inverted Pendulum System

J. Xiao, S. Zhang, Northeastern U., *J. Xiao*, City Coll. of City U. of New York
N. Xi, Michigan State U., USA

This paper presents a motion mode control method for double inverted pendulum system which is based on fuzzy logic and neural network. After the description of the double inverted pendulum system, a fuzzy neural controller is presented which is based on the proposed fuzzy composed variable and the parameters are optimized by back propagation algorithm in neural network. Then motion modes of the system are defined and adjusted online. Experimental Implementation and testing prove its validity.

12:12—12:30

TC1	Space Applications I		Fixture and Grasping	TC2
	Big Sur 1 (14:00—15:30)		Big Sur 2 (14:00—15:30)	
	Marcello Romano, USA	CHAIR	Ming-Yang Cheng, Taiwan	
	Gangbing Song, USA	CO-CHAIR		

Dynamics Analysis of a Cable-Driven Parallel Manipulator for Hardware-In-The-Loop Dynamic Simulation (I)
O. Ma, X. Diao, New Mexico State Univ., USA

This paper describes a preliminary study of the dynamics of a 6-DOF cable-driven parallel manipulator for a potential application in a ground-based hardware-in-the-loop simulator of microgravity dynamics and contact-dynamics of spacecraft or robotic systems. Two basic dynamics problems are studied. One is the inverse dynamics problem and the other is the rigidity and vibration problem. The study results support the feasibility of using such a cable-driven manipulator for hardware-in-the-loop simulation of contact dynamics.

14:00—14:18

Analysis of Fixturing Dynamic Stability in Machining
H. Deng, S. Melkote, Georgia Inst. of Tech., USA

This paper presents a systematic approach for analyzing the dynamic stability of a fixtured workpiece during machining. Insight into the effects of fixture-workpiece system dynamics, material removal, and clamping forces on fixturing stability is obtained. The influence of clamping forces on fixture-workpiece contact stiffness is also investigated. Fixturing stability is checked by monitoring the contact interaction between the workpiece and fixture elements. A dynamic model that predicts workpiece motion subjected to cutting forces and a static model for contact deformation due to clamping are developed to obtain the total contact motion. A simulation example is presented to illustrate the approach.

Time-Optimal Nonlinear Feedback Control for the NPSAT1 Spacecraft (I)
P. Sekhavat, A. Fleming, I. Ross, Naval Postgraduate School, USA

NPSAT1 is a small satellite being built at the Naval Postgraduate School. It uses magnetic actuators and a pitch momentum wheel for attitude control. In this paper, a novel time-optimal sampled-data feedback control algorithm is introduced for closed-loop control of NPSAT1 in the presence of disturbances. The feedback law is not analytically explicit; rather, it is obtained by a rapid re-computation of the open-loop time-optimal control at each update instant. The implementation of the proposed controller is based on a shrinking horizon approach and does not require any advance knowledge of the computation time. Pre-ground-test simulations show that the proposed control scheme performs well in the presence of parameter uncertainties and external disturbance torques.

14:18—14:36

Grasping Objects with the Prototype of Index-Finger PIP Joint Motion Amplifier for Assisting Rheumatoid Arthritis Patients
K. Watanabe, H. Morishita, T. Mori, T. Sato, Univ. of Tokyo, Japan

The authors propose an exoskeletal robotic hand for assisting the rheumatoid arthritis patients physically. In this paper, we categorized the types of exoskeletal devices into five groups, based on the patients' condition or capability of movement. Then, we constructed a prototype of one of the groups, which amplifies the motion of index-finger PIP joint. Some verification experiments were conducted, in which three subjects were directed to pick objects and place them using the device. The results derived prospect that it was feasible to assist the patients with this type of supporting devices.

Multimodal Vibration Control of a Flexible Structure Using Piezoceramics (I)
V. Sethi, G. Song, Univ. of Houston, USA

This paper presents results of multimodal vibration suppression of a smart flexible cantilever beam by using single piezoceramic actuator and a single sensor. Piezoceramics PZT (Lead Zirconate Titanate) patches are surface-bonded on the beam and perform as actuator and sensor. System identification for the dynamics of the first three modes and model reduction techniques are employed to assist in control system design. The state space model from system identification is used for state estimation and development of control algorithm. A linear pole placement controller is designed and simulated using the identified model. Experimental results demonstrate the effectiveness of multimodal active vibration control of the structure using smart materials.

14:36—14:54

Robustness of Power Grasp with Human Skin Characteristics
T. Hiruta, S. Sugamoto, K. Kosuge, Tohoku Univ., Japan

Human skin has anisotropic elasticity. In this paper, we reveal that robustness of power grasp is improved by assuming human-skin-like anisotropic elasticity of fingers. First, we briefly introduce a conventional method to derive contact forces considering compliant contacts between an object and robot fingers. Then, we model human skin characteristic with anisotropic elasticity and propose an algorithm based on a linear programming method to measure robustness of a given power grasp model with a multifingered hand with human-skin-like anisotropic elasticity. Finally, calculation of a stability region for a planar power grasp model shows that the robustness of the power grasp is improved by assuming human-skin-like anisotropic elasticity at contact points.

Control of a Legged Rover for Planetary Exploration Using Embedded and Evolved Dynamical Recurrent Artificial Neural Networks (I)
A. *Bursi, M. Di Perna, M. Massari, G. Sangiovanni, F. Bernelli-Zazzera*, Pol. di Milano, Italy

This paper presents a new method for realizing the control system of a legged rover for planetary exploration. The controller is realized using a class of dynamical recurrent artificial neural networks called CTRNN, and evolutionary algorithms. The proposed approach allows realizing the design of the controller in a modular way, decomposing the global problem into a collection of low-level tasks to be reached. The embodied dynamical neural network realized has been tested on a virtual legged hexapod called N.E.Me.Sys. The neural-controller has a high degree of robustness facing sensors noises and errors, tolerates a certain amount of degradation, but above all it allows the robot performing …

14:54—15:12

A Hybrid System Approach to Kinematic Modelling of Mutlifingered Hand's Finger Gaits
J. Xu, Hong Kong U. of Science and Tech., *G. Liu*, RPI, USA
Z. Li, Hong Kong U. of Science and Tech., Hong Kong

Large-scale motion of the grasped object is one of the tasks,which is involved in practical dextrous manipulation of multifingered robotic hand. When the large-scale motion can not be accomplished only by rolling and sliding of the finger, finger gaiting, or regrasping, is used. In this paper, we propose a joint space representation of grasps, which represents a stable grasp by a set of joints values with several grasping constraints. Using primitives describing the regrasping process with the joint space representation, we build a kinematic model of finger gaiting as a hybrid automaton. In this model, all grasping constraints are involved. Finally, Simulation results verify the validity and efficiency of ...

Realization and Control of a Prototype of Legged Rover for Planetary Exploration (I)
M. Massari, P. Massioni, S. Nebuloni, G. Sangiovanni, F. Bernelli-Zazzera, Pol. di Milano, Italy

This paper concerns the developement of a prototype of a six-legged robot for space exploration. The robot is a testbed for a new control technique based on a peculiar kind of artificial neural network. Accounts are given on the shape and structure of the hexapod, and a brief description of its electronic circuit and computer interface is shown. The paper ends with the results of the tests on two different control systems (a standard one and the neural network based) and the comparison between the properties of the two methods.

15:12—15:30

Manipulation of Deformable Linear Objects with Knot Invariant to Classify Condition
T. Matsuno, D. Tamaki, F. Arai, T. Fukuda, Nagoya Univ., Japan

In this paper, we propose a description method of conditions of rope using a topological model and knot theory. And, we also propose a recognition method to obtain the structure of rope from visual information obtained by the CCD cameras when a robot manipulates a rope. There are many deformable objects such as papers, clothes, and ropes in life space of a person. Robots need skills to manipulate deformable objects, in order to take active parts in such space. However, it is difficult for robots to manipulate deformable objects well and possibility of failure to operate deformable objects cannot be denied. Therefore theoretical framework of error recovery for deformable object manipulation is required. For error recovery system, it is necessary to abstract profitable data from deformable object, which are hyper degree of freedom structures….

TC3	Design Optimization in Mechatronics		Sensors and Sensing Systems	TC4
	Big Sur 3 (14:00—15:30)		Windjammer 1 (14:00—15:30)	
	Marcelo H. Ang, Singapore	CHAIR	Yoshikazu Mori, Japan	
	Reinhard Guserle, Germany	CO-CHAIR	Ruggero Frezza, Italy	

Parametric Optimal Design of a Pinion-Rack Based Continuously Variable Transmission

J. Alvarez-Gallegos, C. A. Cruz-Villar, CINVESTAV-IPN
E.-A. Portilla-Flores, Univ. Autonoma de Tlaxcala, Mexico

An alternative method for mechatronic systems concurrent design using the dynamic optimization framework is presented in this paper. A dynamic optimization problem (DOP) is proposed to obtain the optimal mechanical parameters values of a continuously variable transmission (CVT), where the kinematic and dynamic models are considered besides the performance criterion of the CVT mechanical ef_ciency. In order to solve the DOP, a sequential method is used to convert it into a nonlinear programming (NLP) problem. A SQP algorithm is used to solve the NLP problem.

14:00—14:18

IR Sensor Array for a Mobile Robot

H. Park, S. Baek, *S. Lee,* Hongik Univ., Korea

This paper describes a new sensor system for improving the accuracy of the range information using multiple IR range sensors. Environment and obstacle sensing is the key issue for mobile robot localization and navigation. Laser scanners cover 180ć; and accurate but are too expensive. Radial range sensors such as laser scanner, IR scanner and Ultrasonic range sensor ring have blind spots so that small obstacle not close to the sensor may be easily missed. It is necessary to develop a low cost sensor system which covers 360ć; and with small blind spots. A sensor system with 12 IR range sensors (each rotates ±37.8ć; for overlapping area to reduce the blind spot) is designed and implemented.

Optimal Design of a Hybrid Controller for Antilock Braking Systems

A. Mirzaei, M. Moallem, D. B. Mirzaeian, Isfahan Univ., Iran

Antilock braking systems (ABS) have been developed to reduce tendency of wheel lock and to improve vehicle control during sudden braking especially on slippery road surfaces. In this paper, an optimized hybrid controller using a fuzzy system is proposed for antilock braking systems. The objective function is defined to maintain wheel slip to a desired level so that maximum wheel tractive force and maximum vehicle deceleration are obtained. All components of fuzzy system are optimized using a genetic algorithm and error based optimization technique. The error based global optimization approach is used for fast convergence near optimum point. Simulation results show fast convergence and good performance of the controller for different road conditions.

14:18—14:36

Active Sensing Based Mobile Robot Exploration

J. Bae, *S. Lee,* Hongik Univ., Korea

An algorithm has been developed for robots which explore the environment to measure the physical properties (temperature in this paper). While the robot is moving, it measures the temperature and registers the value in the corresponding grid cell. To reach the local maximum or minimum, simple gradient following is used. Robust estimation of the gradient using perturbation/correlation is described. By introducing the probability of each grid cell, and considering the probability distribution, the robot doesn't have to visit all the grid cells in the environment still providing fast and efficient sensing.

A New Approach for Mechatronic System Design: Mechatronic Design Quotient (MDQ)

R. X. Lu, Nat'l U. of S'pore, Singapore, *C. de Silva*, U. of British Columbia, Canada, *M. H. Ang*, *A. N. Poo*, National U. of S'pore
H. Corporaal, Eindhoven Univ. of Tech., Netherlands

In mechatronic system design, many issues are very complicated and are under multiple design criteria. In this paper a general and integrated approach is presented for the design of complex electro-mechanical systems. The formal approach is based on the concept of Mechatronic Design Quotient (MDQ). Five steps are presented to establish and optimize an MDQ index. The approach is illustrated with respect to the engineering decision making processes incorporated in manipulator design. Various design aspects of the complex problem including the number of degrees of freedom (DOF) ...

14:36—14:54

Cooperative Multi-Target Surveillance Using a Mutational Analysis Approach

A. Goradia, N. Xi, M. Prokos, Z. Cen, M. Mutka, Michigan State Univ., USA

The task of tracking multiple targets using a networked surveillance system is challenging because:(1) multiple targets need to be monitored and tracked continuously so that they will not leave the view of at least one of the sensors; (2) the view of the sensors needs to be optimized so that at a given time targets are observed with a discernable resolution for feature identification; (3) it is important to devise stable control algorithms for accomplishing the surveillance task. This paper presents a mutational analysis approach for shape based control to model a multi-target surveillance scenario. It further presents an optimal multiple sensor task planning algorithms based on the target resolution and priority, to achieve optimal coverage of multiple targets using a surveillance network.

Optimization Alternatives of Mechatronic Systems Containing Switched Reluctance Drives

D. Gerling, A. Schramm, Univ. of Federal Defense Munich, Germany

In mechatronic systems there are several different kinds of optimization alternatives, in particular mechanic, electronic and control means. In this paper, these different possibilities are investigated and compared for a special example: A switched reluctance drive (SRD), energized from a weak supply net, is coupled to an internal spindle-gear to generate a linear output force. Special attention is paid to cost-effective means of optimization.

14:54—15:12

Position Estimation for a Mobile Robot Using a Novel Accelerometer : Cantilever-Type Accelerometer with Impedance Detector

Y. Mori, Ibaraki Univ., *M. Uchiyama*, Tokyo Metropolitan Univ.
A. Goto, AMITEQ, Co., Ltd., Japan

In this paper, we present a method of position estimation for a mobile robot using a novel accelerometer. For the purpose of estimating the accurate position of a robot, we developed a new accelerometer and propose a method. The impedance detector, "Inductcoder", provides digital data. The moving module consists of a weight and a cantilever, which causes no drift. The performance of these devices was evaluated experimentally. We propose an idea to reduce errors and to improve the reproducibility using a piezo actuator. In addition, in order to prevent the estimation errors from increasing, a stop condition is discussed.

Application of Multidisciplinary Simulation and Optimization of Mechatronic Systems in the Design Process

R. Guserle, M. F. Zaeh, Tech. Univ. München, Germany

Dynamic and thermal properties crucially influence the attainable accuracy of machine tools. Therefore, dynamic loads and thermal influences on structural components and on feed drive systems are important factors to be considered in the design process of mechatronic systems. This publication describes the integration of CAx-tools to enable a fast and efficient modeling and optimization of machine tools. Through the development of customized FE- and MBS-Analyses, the dynamic state of components is monitored. Based on a FEA-extension, an analysis of thermal influences on machine tool movements was also conducted in computational models. Using experimental research the models have been verified. Through the developed method, an estimation of the TCP-shift can be estimated.

15:12—15:30

Model Based GPS/INS Integration for High Accuracy Land Vehicle Applications: Calibration of a Swarm of MEMS Sensors

S. Zilli, R. Frezza, A. Beghi, Univ. di Padova, Italy

We consider the problem of reconstructing the trajectory of a mobile mapping system based on a mid-size van. Mobile mapping requires, of course, high accuracy. Usually this is achieved by resorting to costly GPS/INS integrated systems. The INS, in particular, must guarantee high performance when the GPS signal is occluded. This paper concerns the possibility of using, in alternative, a swarm of low cost MEMS accelerometers mounted in random positions and orientations. In order to be able to reconstruct the trajectory, the relative position and orientation of each accelerometer should be known. Here, we propose a method for an automatic calibration of the cloud of MEMS sensors and an algorithm for trajectory reconstruction by GPS and MEMS accelerometers integration.

TC5

Learning Control in Mechatronics

Windjammer 2-3 (14:00—15:30)

Nader Sadegh, USA — CHAIR

Takayuki Nakamura, Japan — CO-CHAIR

MEMO

Command-Based Iterative Learning Control for Compensation of Servo Lag and Friction Effects — 14:00—14:18

M.-S. Tsai, M.-T. Lin, *H.-T. Yau,* National Chung Cheng Univ., Taiwan

A command-based iterative learning control (ILC) architecture is proposed to compensate for friction effect and to reduce tracking error caused by servo lag. The proposed methodology utilizes the learning algorithm which updates the input commands based on the tracking errors from the previous machining process. It is shown that, for tracking a circle, the quadrant protrusions caused by friction can be reduced substantially by the updated command containing a concave shape located at the crossing of the zero velocity. Finally, analytical simulation and experimental results demonstrate that the command-based ILC algorithm can enhance the tracking performance significantly.

High Performance Control of Active Camera Head Using PaLM-Tree — 14:18—14:36

T. Nakamura, Y. Sakata, *T. Wada, H. Wu,* Wakayama Univ., Japan

In this paper, we propose a new feedback-error-learning controller enhanced by the PaLM-tree that is an easy-to-use function approximator developed by our research group. We investigate the ability of our feedback-error-learning controller by applying it to controlling an active camera head to pursuit a moving target with high accuracy and high response. The PaLM-tree learns the inverse model in the feedback-error-learning scheme correctly. Although our active camera head has unknown mechanical friction and our closed-loop control system has a relatively large latency, our active camera head can pursuit eye movement by our feedback-error-learning controller based on the PaLM-tree. We confirmed that our method could achieve high-performance control over the tuned feedback control.

From Iterative Learning Control to Robust Repetitive Learning Control — 14:36—14:54

Y. Wang, D. Wang, B. Zhang, Nanyang Tech. U., Singapore

Y. Ye, Zhejiang Univ. of Finance and Econ., China

In this paper, a Robust Repetitive Learning Control (RRLC) scheme is proposed based on the frequency domain ILC design methodologies. A linear phase lead is introduced in the repetitive module to compensate the phase lag and widen the cutoff frequency of Q filter. The periodic disturbance rejection performance of system is improved. The robustness stability and performance of proposed scheme is analyzed and synthesis method are proposed to achieve overall system robust performance. The simulation results of active vibration control of Hexapod show that the proposed RRLC scheme can reject periodic disturbances significantly.

Control of Discrete-Time Systems Via Online Learning and Estimation — 14:54—15:12

P. Opdenbosch, N. Sadegh, Georgia Inst. of Tech., USA

Online learning state trajectory control for discrete-time systems is considered herein. An improvement to a method previously developed that learns the control input as a function of the desired states for state trajectory tracking control is investigated. The improved method splits the control input into a nominal map and a learned adjustment in addition to online estimation of control parameters such as the system's Jacobian and Controllability matrix. A neural network structure called the Nodal Link Perceptron Network learns the adjustment of the nominal map as a function of the desired states while the Jacobian matrix and the Controllability matrix are estimated online via a modified Broyden method to achieve the overall control input.

Learning Distributed Grasp in Presence of Redundant Agents — 15:12—15:30

A. H. Elahibakhsh, M. Nili Ahmadabadi, U. of Tehran, Iran, *F. Janabi-Sharifi*, Ryerson U., Canada, *B. Nadjar Araabi*, U. of Tehran, Iran

Learning distributed object grasp by a group of robots with redundant members is the main focus of this paper. We tackle the problem of learning form closure grasp for planar convex objects by multiple and redundant non-communicating robots without any information about the shape of objects. Agents' states and actions are designed such that the group learns grasping different objects using Q-learning method and a credit assignment algorithm based on knowledge evaluation. It is shown that the team learns grasping different objects and can be extended for distributed grasp of deformable objects.

TD1	Space Applications II		Flexible Manipulators and Structures	TD2
	Big Sur 1 (15:45—17:15)		Big Sur 2 (15:45—17:15)	
	Marcello Romano, USA	CHAIR	Kok-Meng Lee, USA	
	Michčle R Lavagna, Italy	CO-CHAIR	Yan-Ru Hu, Canada	

15:45—16:03

Optimal Path Planning for Planetary Exploration Rovers Based on Artificial Vision System for Environment Reconstruction (I)

M. Massari, E. Ceriani, L. Rigolin, F. Bernelli-Zazzera, Pol. di Milano, Italy

In this paper an optimal path planning algorithm for rover navigation is presented. The algorithm is based on an artificial vision system which reconstructs the digital elevation map of the environment through the use of two stereo cameras. On the basis of this digital elevation map the optimal path is generated with a simulated annealing approach. The direct use of the information in the digital elevation map allows to design a detailed path which takes care of each detected feature of the environment and of the cinematic limitation of the rover.

Shape Estimation of Inflatable Space Structures Using Neural Network

F. Peng, Y.-R. Hu, A. Ng, Canadian Space Agency, Canada

Inflatable space structures need to maintain in a desired shape in space in order to achieve satisfactory performance. The active shape control technique has shown its advantages in solving this problem. One difficulty to realize an active control system in space is how to establish a model that reflects the structure shapes under different environment and boundary tensions. This paper proposes a neural network scheme to estimate the shape of inflatable structures. A neural network is trained to map environment information and control tensions into the structure shape. Validation studies showed the proposed scheme gave very good estimations of the membrane flatness.

16:03—16:21

Space System Formation Planning and Scheduling: A Distributed Approach (I)

A. Brambilla, *A. Da Costa, A. E. Finzi, M. R. Lavagna,* Pol. di Milano, Italy

The paper presents a distributed approach to the planning-scheduling to be faced by a space systems formation, to accomplish specific mission goals. A multi-agent architecture is here selected to cope with flexibility, reliability and robustness requirements. Each physical unit works coordinates its own resource-activity scenario with the other units to accomplish both personal and shared activities needed to gain the required goals. To this end, distributed temporal and resource nets are solved. Specific communication protocol and negotiation strategies are proposed to cope with the distributed problem solving.Simulations run on a 3-agents scenario of rover devoted to planetary surface exploration show the validity of the proposed approach.

An Analytical Method for Design of Compliant Grippers with Macro/Micro Manipulation and Assembly Applications

C.-C. Lan, K.-M. Lee, Georgia Inst. of Tech., USA

This paper presents a method based on Nonlinear Constrained Optimization techniques to analyze contact problems of a compliant gripper that gains its dextral manipulation by the flexural motion of its fingers. For a planar compliant gripper, this formulation reduces the domain of discretization by one dimension. Hence the formulation is simpler and can be computed more efficiently than other methods such as finite element analysis. As this method is rather generic, its use will facilitate design analysis and optimization of compliant devices. We illustrate these attractive features with two types of applications; macro-handling and micro-assembly.

16:21—16:39

Game Theory and Possibilistic Logic to Face the Space Mission Preliminary Design Optimization: A Coevolutive Architecture with a Semicooperative Protocol (I)

M. R. Lavagna, A. Mafficini, Pol. di Milano, Italy

The paper presents a possible approach for a support tool for the space system preliminary design in the very early phases. The proposed method generates the inputs the team of engineers works on, to design the space system preliminary configuration. The tool, starting from some generic and qualitative mission objectives, such as the planet to be visited and the number of possible on-board instruments, generates all possible high level architectures, and, thanks to a co-evolutive multi-objective optimization, sorts the final Pareto hyper-surface solutions, according to a predefined metric. Validations and simulations, run on real data given by scenarios and preliminary study results obtained …

A Mathematical Model to Describe Bending Mechanics of Polypyrrole (PPy) Actuators

G. Alici, U. of Wollongong, Australia, *P. Metz*, Inst. Francais De Mecanique Avancee, France, *G. M. Spinks*, U. of Wollongong

In order to make use of conducting polymer actuators such as PPy actuators suitable for many cutting edge applications, and more importantly to provide enhanced degrees of understanding and predictability in quantifying their performance, it is needed to establish a valid mathematical model of such actuators. With this in mind, the aim of this study is to establish and experimentally validate a lumped-parameter model of strip-type PPy actuators for use in improving their displacement and force outputs. We draw an analogy between the thermal strain and the real strain in the PPy actuators due to the volume change to set up the mathematical model, which is a coupled structural/thermal model...

16:39—16:57

A Visual Servoing Control System for Lightweight Robotic Manipulator (I)

M. Attolico, O. Cargnel, R. Cazzoli, A. Davighi, F. Bernelli-Zazzera, Pol. di Milano, Italy

Traditional spacecraft structures were rigid, but there is now an increasing trend towards lighter spacecraft whose structures and appendages are flexible. It is thus more and more important to consider the interaction between the structural elements of the spacecraft and its attitude and position control systems. The aim of this research program is to realize a visual-servoing control system for a couple of two aluminum and composite material arm manipulators, innovative because of the very high flexibility. Some experimental tests of tracking, to validate the system, are presented on a micro-gravity simulation set-up realized for this project.

Modeling on a Gimbal with an Antenna

J. H. Baek, J. C. Kim, S.-C. Choo, NEX1 Future Co. Ltd., Korea

A model of an azimuth driving servo system with a flexible antenna in a tracking system was derived in this work. The validity of the model was verified by comparing the results of the model with experimental results. When modeling the dynamics of a gimbal with an antenna, the antenna should be considered as a flexible body. The effect of reducing the magnitude of the backlash that results in extending the bandwidth in a system with a flexible antenna is smaller than the effect of reducing the magnitude of the backlash in a system with a stiff antenna. When there is a need to reduce the weight and extend the bandwidth, the derived model enables the design of a tracking system to be optimized.

16:57—17:15

On-The-Ground Experiments of Autonomous Spacecraft Proximity-Navigation Using Computer Vision and Jet Actuators (I)

M. Romano, US Naval Postgraduate School, USA

This paper presents the status of the research on autonomous proximity-navigation and spacecraft docking, which is on-going at the Space Robotics Laboratory of the NPS. A test-bed has been designed and is in the advance integration phase, which can be used for validating analytical and numerical results regarding dynamic models and control laws. The test-bed consists of two spacecraft models floating on a flat surface to simulate in 2D the weightlessness of the orbital flight. A custom-developed Vision Navigation Sensor is used to determine the relative position and orientation of the two spacecraft. This paper presents an overall description of the test-bed and reports the preliminary experimental results of autonomous navigation of the chaser-spacecraft in the proximity of the target.

Development and Analysis of a Snake Robot with Flexible Connectors

Y.-C. Lin, J. J. Chou, National Taiwan Univ., Taiwan

In this study, a snake robot with flexible connectors and distributed control system was developed and an optimal velocity planning approach was investigated under the constraints of path, kinematics and the dynamics of the robot. The robot includes five modules which are connected by flexible connectors. Each module is driven by two stepper motors and controlled in a differential way for its direction and speed by microcontrollers. The flexible connectors make the robot's motion smoother and more snake-like in its movement. A properly designed robot should track the planned path accurately and smoothly. Furthermore, it would arrive at its destination in a minimum amount of time without sliding or losing steps if the optimal velocity planned by the study is applied.

TD3	Computational Models and Methods		Magnetic Bearings	TD4
	Big Sur 3 (15:45—17:15)		Windjammer 1 (15:45—17:15)	
	Yi Su, Singapore	CHAIR	Eric Maslen, USA	
	Ming-Yang Cheng, Taiwan	CO-CHAIR	Dong-Chul Han, Korea	

On Real-Time Contour Error Estimation for Contour Following Tasks
M.-Y. Cheng, C.-C. Lee, National Cheng Kung Univ., Taiwan

In contour following applications, one of the main concerns is how to reduce contour errors. The common approach to this problem is to design the contour controller based on the real-time contour error information. However, for the free-form contour following tasks, there is a lack of effective algorithms for calculating contour errors in real time. To overcome this difficulty, this study proposed a real time contour error estimation algorithm. Based on the estimated contour error obtained from the proposed algorithm, an integrated motion control scheme is employed to improve the machining accuracy for a contour following task. Experimental results indicate that both the proposed contour error estimation algorithm and the integrated motion control scheme exhibit satisfactory performances.

15:45—16:03

Magnetic Levitation Design for the PediaFlow Ventricular Assist Device (I)
M. D. Noh, Chungnam National U., Korea, *J. F. Antaki*, Carnegie Mellon U.
M. Ricci, J. Gardiner, E. Prem, LaunchPoint Tech. LLC
H. S. Borovetz, U. of Pittsburgh, *B. Paden,* U. of California Santa Barbara, USA

In this paper, we describe a design process for a pediatric ventricular assist device (PVAD). The central part of the device is a magnetically levitated rotating pump which creates a pressure rise (~100mmHg) at a required flow rate (~0.5L/min) suitable for infants and small children. We have considered several different pump topologies, of which an axial mixed--flow pump configuration was chosen for further development. The pump impeller is supported by two radial permanent--magnet passive bearings. In contrast to the radial suspension, the axial motion of the impeller is actively controlled using a voice--coil actuator. A toroidally--wound motor drives the pump….

Emotional Mechatronics--A Concept Whose Time Will Come (I)
J. Baker, Baker Adaptive Optics, USA

Megapixel cameras and a plethora of other high bandwidth multi-sensory devices exist together with satisfactory data I/O concurrent with inexpensive gigaflop processing capabilities, yet we cannot tackle some of the most basic problems of automation. And, the building blocks of robotics technology improves almost daily. What place, if any, do the concepts of emotion, social interaction, and possibly even religion have to do with hardware control? It is time for B.E.A.U.T'Y, a unification theory of automation to help use what we already have to its full potential and to help us determine where should put our efforts in future hardware and algorithmic development. I present some interesting early observations and results of such a theory now in the early stages of development.

16:03—16:21

A Q-Value Measurement for Damping Evaluation of AMB Rotors
O. Matsushita, *F. Hiroyuki*, *I. Makoto*, National Defense Acad.
S. Muneharu, National Inst. of Advanced Industrial Science & Tech., Japan

The sensitivity function of feedback control systems is recommended for AMB (Active Magnetic Bearing) equipped rotors to evaluate the stability margin. Alternatively before rotor operation, we need to predict the resonance severity called Q-value. In this paper, the sensitivity and the Q-value are discussed and the difference is made clear. How to obtain the Q-value from the open loop transfer function is also discussed. Our proposed Q-value function is numerically and experimentally demonstrated so well for several AMB rotors. This obtained Q-value peak agrees with exact values calculated by eigenvalues and/or measured by the half power point method.

Approximate Modeling of a Class of Nonlinear Mechanical Oscillators Using Fuzzy Systems and Its Application to Control Design
H. Schulte, Univ. Kassel, Germany

An effective modeling of nonlinearities and the analysis of the influence on the closed-loop dynamics in mechatronic systems such as servo systems is often crucial for high performance applications. For this we propose an analytical method of approximate modeling of a class of nonlinear mechanical oscillators using fuzzy systems. The emphasis in this work will be on a systematic description of the construction of fuzzy systems from known nonlinear models and an error analysis as a function of model complexity. Finally, its application as a model framework for an effective gain-scheduling control design method will be discussed.

16:21—16:39

Effects of Actuator Dynamics in Active Control of Surge with Magnetic Thrust Bearing Actuation (I)
D. Sanadgol, E. Maslen, Univ. of Virginia, USA

Control of surge in centrifugal compressors is accomplished by modulating the clearance of the impeller with a magnetic thrust bearing. The controller is designed with the objective that system trajectories remain on the compressor characteristic ensuring zero steady state offset of impeller and maintaining efficiency of the compressor. Special attention is paid to the dynamic effects of the actuator, which is included explicitly in the control synthesis. Results from simulations of the nonlinear model for a single stage high speed centrifugal compressor show that the compressor characteristic curve can be stabilized with acceptable control authority and modest dynamic requirements.

Hardware-In-The-Loop-Simulation of a Vehicle Climate Controller with a Combined HVAC and Passenger Compartment Model
D. Michalek, C. Gehsat, R. Trapp, Behr-Hella Thermocontrol
T. Bertram, Tech. Univ. Ilmenau, Germany

In case of the Software- and Hardware-in-the-Loop-Simulation (SIL- and HIL-Simulation) for an air conditioning controller, models of the heating, ventilation and air conditioning elements (HVAC) and the passenger compartment are necessary. A main demand for the HIL-Simulation is the real time capability. Therefore it is a challenge to create simple but accurate models that enable a fast calculation of the wanted values. Both models, the HVAC and the single zone passenger compartment model and their interfaces will be presented. Further results of both models interacting in a HIL-Simulation on a commercial hardware platform connected via interfaces to the climate controller will be shown.

16:39—16:57

Control Designs for Low Loss Active Magnetic Bearings (I)
B. C. D. Wilson, Air Force Res. Lab.
P. Tsiotras, *B. Heck-Ferri*, Georgia Tech., USA

Highly efficient electromechanical flywheel batteries (FWBs) require the use of low-loss active magnetic bearings (AMBs). Since the losses in the FWB, and in AMB itself, are proportional to the square of the electromagnet flux, it is imperative to minimize the bias flux (or current) customarily used in the AMB control design. This paper illustrates the experimental implementation of a generalized complementary flux constraint to allow for zero- and low-bias operation. Furthermore, passivity theory is used to remove the zero-bias control law singularity. Experimental evidence supports this claim from a time and frequency domain perspective.

Research on Approach for Pole Beacon Determination of Logistic System Based on the Fuzzy Set Theory
X. Wang, Jiliang U., *Y. Zhang*, Zhejiang U. of Science and Tech.
Z. Qing, Jiliang Univ., China

For two master businesses (distribution and sorting) in one logistics system, Benchmarking implementation strategy is designed, and it is key to discuss the problems about system evaluation and mark-post quantification. Thereinto, the system is evaluated by means of Fuzzy set theory; through comparing evaluation result, a score of ideal performance is set. Furthermore, according to the rout of hierarchical calculating of fuzzy evaluation, a set of improved fuzzy values for each operation at the bottom of system hierarchy is reckoned against fuzzy evaluation calculating rout. Finally, it expatiate on the meaning of Benchmark combined with DEA and the effect of small mark-post …

16:57—17:15

Speed-Dependent Tool Tip Compliance Measurement of a High-Speed Machine Tool Spindle Using an Active Magnetic Bearing (AMB)
H.-J. Ahn, J.-H. Kim, Seoul National U., *J.-J. Lee*, ROKAF HQ
J.-H. Kim, Seoul National U., *D.-Y. Jang*, Seoul National U. of Tech.
D.-C. Han, Seoul National U., Korea

In this paper, we proposed a new measuring method of the speed-dependent tool tip compliance of a high-speed machine tool spindle using an AMB (active magnetic bearing). Single sine wave current excitation is injected through the AMB, and the displacement and force responses are measured with a CCS (cylindrical capacitance sensor) and a dynamometer, respectively. Then, the tool tip compliance can be estimated accurately without any phase delay by dividing the frequency response from the current to the displacement by that from the current to the force. A flexure test rig was designed to ….

TD5

Mechatronics in Manufacturing Processes

Windjammer 2-3 (15:45—17:15)

Hui Zhang, USA — CHAIR

Michael Bailey-Van Kuren, USA — CO-CHAIR

MEMO

An Intelligent Disassembly Assistant for Man-Machine Demanufacturing (I)

M. Bailey-Van Kuren, J. Soltani, Miami Univ., USA

15:45—16:03

In order to handle the complexity of demanufacturing operations, a combined man-machine system is proposed that incorporates projector-vision technology. An intelligent disassembly assistant has been developed to provide a flexible and efficient method for facilitating man-machine demanufacturing. The assistant is comprised of a set of software modules that are processed in a distributed computing environment. Hardware and software components of the intelligent assistant are identified. The assistant determines the base elements of the structure, checks for stability, and then determines a disassembly sequence. A projector-vision system provides information to a human operator and detects operations performed on the product, adapting to unexpected human operator behavior.

A Measurement System Based on Capacitance Sensors for Geometric Error of a Miniaturized Machine Tool

J.*-H. Lee, Y. Liu, S.-H. Kweon, S.-H. Yang, Y.-S. Kim*, Kyungpook Nat'l U., Korea

16:03—16:21

Miniaturized machine tool has been presented as a promising technique for machining miniature components due to its advantages such as miniaturized error sources, less heat dissipation and no limitation of the materials. To achieve submicron machining accuracy, geometric errors of a miniaturized machine tool should be accurately identified and compensated. In this paper, a novel multi-degree-of-freedom measuring system with five capacitance sensors and a sensing target is proposed for simultaneous measurement of two straightness, roll, yaw and pitch error motions along one moving axis of a miniaturized machining tool. An error estimation algorithm is developed for calculation ….

Intelligent Manipulation of Non-Rigid Parts Parts in Industry Applications

C. Wögerer, G. Nittmann, P. Tatzer, ARC Seibersdorf Res. GmbH, Austria

16:21—16:39

The problems by manipulation of non rigid and flabby, ductile and adhesive parts is an incidental and well known challenge in industrial automation practice. These problems are almost very complicated in each case. Nowadays many assembling, handling and mounting processes of such products were still done by manual activities. This is often the reason that industrial productions move from central Europe to countries with low labour and so low production costs. For an efficient handling of theses parts it is necessary to develop particularly intelligent and convenient Interfaces form the handling device to the material and to adapt it especially to the product in each application.

Machining with Flexible Manipulator: Toward Improving Robotic Machining Performance

H. Zhang, *J. Wang, G. Zhang, Z. Gan*, ABB, Inc.

Z. Pan, *H. Cui, Z. Zhu*, Stevens Inst. of Tech., USA

16:39—16:57

This paper presents the critical issues and methodologies to improve robotic machining performance with flexile industrial robots. Compared with CNC machines, the stiffness of industrial robots is significantly lower, resulting in unacceptable quality and lower productivity. The problem is treated with a novel methodology that consists of stiffness modeling, real-time deformation compensation for quality and controlled material removal rate for efficiency. Experimental results show that higher productivity as well as better surface accuracy can be achieved, indicating a promising and practical use of industrial robots for machining applications that is not possible at present.

Intelligent Dual-Speed Design for Face-Up Chemical Mechanical Polishing

Y.-Y. Chen, J.-C. Lin, National Taiwan Univ., Taiwan

16:57—17:15

Chemical Mechanical Polishing (CMP) has become increasingly important as the feature size of the IC processing stepping into under 0.25 ?m and the range of nanometers. The decreasing feature size and the increasing complexity of circuit layouts mandate the uniformity of the processing surfaces in multi-layer integrated circuits. To further improve the planarization process, the traditional face-down CMP configuration is being replaced by the face-up design for its local planarity, small form factor, and economy in material cost. In this paper, an intelligent dual-speed polishing procedure is proposed for the face-up CMP design. The integration of two different polishing speeds with parameter optimization can significantly reduce the non-uniformity of the wafer surface….

WA1	Multi-Robot System		Rehabilitation Robots	WA2
	Big Sur 1 (09:30—10:42)		Big Sur 2 (09:30—10:42)	
	Warren Dixon, USA Kazuhiro Kosuge, Japan	CHAIR CO-CHAIR	Rajiv Dubey, USA William Singhose, USA	

09:30—09:48

Knowledge Based Evolutional Multiple Robot System

K. Matsuda, H. Ishihara, Kagawa Univ., Japan

In this paper, we have discussed on the effect of the knowledge sharing for the multiple robot system which is equipped with the advanced telecommunication devices. These days, the broad bandwidth telecommunication method has been brought into the world of robotics. This has enabled the mobile robots to perform advanced communication. This is not only for master's or administrator's command use but for the exchange of the knowledge obtained from the operation. This knowledge sharing system will realize the evolution of the knowledge level of the entire module group and help the equalization of the intelligence level. Therefore, we propose the utilization of the knowledge sharing robot system at manufacturing scenes, and demonstrate the effects by a simplified simulation.

Wheelchair-Mounted Robotic Arms: Analysis, Evaluation and Development

R. Alqasemi, E. McCaffrey, K. Edwards, R. Dubey, U. of South Florida, USA

This paper focuses on kinematic analysis, evaluation and design of wheelchair mounted robotic arms (WMRA). It addresses the kinematics of the WMRA with respect to its ability to reach common positions while performing activities of daily living (ADL). A procedure is developed for the kinematic analysis and evaluation of WMRAs. In an effort to evaluate two commercial WMRAs, the procedure for kinematic analysis is applied to each manipulator. Design recommendations and insights with regard to each device are obtained and used to design a new WMRA to overcome the limitations of these devices. This method will benefit the researchers by providing a standardized procedure for kinematic analysis of WMRAs that is capable of evaluating independent designs.

09:48—10:06

Navigation and Control of a Wheeled Mobile Robot

J. Chen, D. Dawson, Clemson U., *W. Dixon, T. Galluzzo*, U. of Florida, USA

Several approaches for incorporating navigation functions into different controllers are developed in this paper for task execution by a nonholonomic system (e.g., a wheeled mobile robot) in the presence of known obstacles. The first approach is based on the use of a 3-dimensional (position and orientation) navigation function that is based on desired trajectory information. The navigation function yields a path from an initial condition inside the free configuration space of the mobile robot to a stable equilibrium point. A differentiable, oscillator-based controller is then used to enable the mobile robot to follow the path and stop at the goal position. A second approach is developed for a 2-dimensional (position-based) navigation function that is constructed using sensor.

Bed-Type Robotic System for the Bedridden

K. -H. Seo, C. Oh, T.-Y. Choi, J. -J. Lee, KAIST, Korea

An Intelligent Bed Robot System (IBRS) is proposed to help the elderly and the disabled for their independent life in bed. The IBRS is a special bed equipped with two robot arms and an array of pressure sensors attached onto the mattress. The pressure distribution on the mattress is used to estimate the pose of the patient, and an appropriate assistance is provided by the robot arms.

10:06—10:24

Cooperative Distributed Robust Control of Modular Mobile Robots with Bounded Curvature and Velocity

X. Zhu, Y. Kim, M. Minor, Univ. of Utah, USA

A novel motion control system for Compliant Framed wheeled Modular Mobile Robots (CFMMR) is studied in this paper. This type of wheeled mobile robot uses rigid axles coupled by compliant frame modules to provide both full suspension and enhanced steering capability without additional hardware. The proposed control system is developed by combining a bounded curvature-based kinematic controller and a nonlinear damping dynamic controller. In particular, multiple forms of controller interaction are examined. A two-axle scout CFMMR configuration is used to evaluate the different control structures. Experimental results verify efficient motion control of posture regulation.

Development of Straight Style Transfer Equipment for Lower Limbs Disabled "ABLE"

Y. Mori, Ibaraki Univ., *J. Okada*, Tokyo Metropolitan Univ.
K. Takayama, Honda R&D Co., Ltd., Japan

We developed straight style transfer equipment for a person with disabled legs. This equipment consists of three modules: a pair of telescopic crutches, a powered lower extremity orthosis, and a pair of mobile platforms. The prototype of the power lower extremity orthosis is presented. Cooperative operations using three modules are discussed through simulations. In previous studies, these motions had a problem with adaptability to the environment and safety because it had executed the movement that relied on telescopic crutches. In this paper, a new motion technique suitable for an actual environment is proposed, and it is compared with the previous method.

10:24—10:42

Deformable Caging Formation Control for Cooperative Object Transporation by Multiple Mobile Robots

Z. D. Wang, Y. Hirata, K. Kosuge, Tohoku Univ., Japan

This paper addresses the problem of multi-robots object transportation by using the concept of Object Closure. In contrast to Form or Force Closure, Object Closure is a condition under which the object is trapped so that there is no feasible path for the object from the given position to any position that is beyond a specified threshold distance. In this paper, the Object Closure Margin used to decide the caging formation is addressed and a decentralized control algorithm to perform a large object handling by controlling the density of robots in the caging formation is proposed.

Playing Assistant for Physical Handicapped Children

G. Kronreif, M. Kornfeld, M. Fuerst, C. Wögerer, B. Prazak, S. Mina,
ARC Seibersdorf Res. GmbH, Austria

The work described in this paper is mainly based on a qualitative study which is aimed to analyse how children with physical handicaps play in comparison with abled children. In this study it was proved through many statements from parents and therapists that play is an important part of the development of a child, but that severe physically handicapped children are very restricted in their possibilities to play. Many of these children only have the possibility to watch and observe how other children or their brothers and sisters or parents are playing and so they compensate their lack of experience only to some extent. The study finally concludes that for children with severe physical handicaps a toy robot system can be a reasonable solution.

WA3	Artificial Intelligence in Mechatronics		Neuro-Fuzzy Control in Mechatronics	WA4
	Big Sur 3 (09:30—10:42)		Windjammer 1 (09:30—10:42)	
	Shigeki Sugano, Japan	CHAIR	Hideki Hashimoto, Japan	
	Suman Chakravorty, USA	CO-CHAIR		

An Evolutionary Approach for Robust Layout Synthesis of MEMS

Z. Fan, Tech. U. of Denmark, Denmark, *J. Wang*, United Tech. Res. Center
E. Goodman, Michigan State Univ., USA

The paper introduces a robust design method for layout synthesis of MEM resonators subject to inherent geometric uncertainties such as the fabrication error on the sidewall of the structure. The robust design problem is formulated as a multi-objective constrained optimisation problem after certain assumptions and treated with multi-objective genetic algorithm (MOGA), a special type of evolutionary computing approaches. Case study based on layout synthesis of a comb-driven MEM resonator shows that the approach proposed in this paper can lead to design results that meet the target performance and are less sensitive to geometric uncertainties than typical designs.

09:30—09:48

Using Adaptive Neuro Fuzzy Inference System in Developing an Electrical Arc Furnace Simulator

F. Janabi-Sharifi, G. Jorjani, *I. Hassanzadeh,* Ryerson Univ., Canada

This paper presents the use of Adaptive Neuro- Fuzzy Inference Systems (ANFIS) in simulating the regulator control loop of the Electrical Arc Furnace (EAF). The regulator loop is the core part of steel making EAF, which controls positioning of the electrodes. The non-linearity and complexity of EAF makes it very difficult to use the classical mathematical modeling techniques in building the process simulator. This research shows that, the EAF regulator loop could be modeled with the use of ANFIS as non-parametric modeling method. The effort is extended to put together the different parts of the model in a cascade and come up with a complete regulator loop simulator.

Self-Organizing Algorithm for Logic Circuit Based on Local Rules

C. H. Kim, T. Ogata, S. Sugano, Waseda Univ., Japan

This study discusses a learning algorithm for autonomous robots that has five characteristics including autonomous exploration of effective output, low calculation costs, _;capability for multi-tasking, reusing past knowledge, and handling time series. We propose the use of self-organizing network elements (SONE) as a method for creating learning systems that provide these characteristics. Using this method, we created and evaluated a Self-Organizing Logic Circuit. The results of our experiments showed that this learning system met the requirements by being capable of creating a basic logic circuit, learning additional knowledge, controlling a simple robot in a simulation, and solving a maze problem.

09:48—10:06

Haptic Modeling for Liver Cutting Based on Fuzzy Neural Network

W. Song, K. Yuan, Inst. of Automation, Chinese Acad. of Science, China

Based on image processing and 3D magnetic tracking, a scalpel adjusted for cutting parameters acquisition was designed, and the performance was validated from liver cutting. Then a method for fuzzy system modeling was presented, that is, each input variable space was partitioned equally at first, and the premises and the total number of fuzzy rules were decided next, then the consequent parameters were learned and the fuzzy membership functions (MF) of the input variables were optimized by using a neurofuzzy modeling technique based on ANFIS. Finally a haptic modeling for liver cutting was established.

Development of a Fuzzy Logic Based Mobile Robot for Dynamic Obstacle Avoidance and Dynamic Goal Acquisition in an Unstructured Environment

R. Malhotra, A. Sarkar, Vellore Inst. of Tech., India

This paper presents the design of a mobile robot for obstacle avoidance in an environment about which no a-priori information is available and which consists of static as well as moving obstacles. The paper concerns itself with the design of a fuzzy brain for the mobile robot, its integration into the control system and the sensor system used for the detection of obstacles in its workspace. The obstacle avoidance strategy of the robot is based on the artificial potential field method. A fuzzy logic based system is used to implement this strategy since it reduces the computational effort required in the implementation of the artificial potential field method.

10:06—10:24

An Adaptive Fuzzy-Neural Controller for Multivariable System

J. Xiao, Northeastern U., China, *J. Xiao*, City Coll. of City Univ. of New York
X. Xu, Northeastern U., China, *N. Xi*, Michigan State Univ., USA

This paper presents an adaptive fuzzy-neural controller for multivariable system which incorporates the advantage of fuzzy logic and neural network. It is very difficult to design and realize a single stage fuzzy controller for the problem of multivariable system as inverted pendulum. After the description of the research background of quadruple inverted pendulum system, a fuzzy-neural controller is proposed which is based on three dimension fuzzy composed variable and the parameters are optimized by back propagation algorithm in neural network. And the parameters could be adjusted online further. The proposed method gives a solution to design and realize high dimension fuzzy controller in multivariable system. Simulation shows its validity.

Intelligent Exploration of Unknown Environments Using Vision Like Sensors

S. Chakravorty, J. L. Junkins, Texas A&M Univ., USA

In this work we present a methodology for intelligent path planning in an uncertain environment using vision like sensors. We show that the problem of path planning can be posed as the adaptive control of an uncertain Markov decision process. The strategy for path planning then reduces to computing the control policy based on the current estimate of the environment, also known as the ``certainty equivalence'' principle in the adaptive control literature. We propose a Monte-Carlo based estimation scheme, incorporating non local sensors, for estimating the probabilities of the environment process, which significantly accelerates the convergence of the associated path planning algorithms.

10:24—10:42

Mobile Agent in the Intelligent Space Which Can Learn Human Walking Behavior

P. T. Szemes, T. Sasaki, H. Hashimoto, Univ. of Tokyo, Japan

The knowledge of human walking behavior has primary importance for mobile agent in order to operate in the human shared space, with minimal disturb of other humans. This paper introduces such an observation and learning framework, which can acquire the human walking behavior from observation of human walking, using CCD cameras of the Intelligent Space. The proposed behavior learning framework applies Fuzzy-Neural Network to approximate observed human behavior, with observation data clustering in order to extract important training data from observation. Preliminary experiment is shown to demonstrate the merit of the introduced behavior.

WA5

Motion Control

Windjammer 2-3 (09:30—10:42)

Tsu-Chin Tsao, USA — CHAIR

Reza Langari, USA — CO-CHAIR

MEMO

Laser Beam Raster Scan under Variable Process Speed - an Application of Time Varying Model Reference Repetitive Control System

J. Wang, T. -C. Tsao, UCLA, USA

09:30—09:48

A laser beam raster scanning problem, where the laser beam must traverse certain trajectories on a moving platform is addressed in this paper. The raster scanning motion is periodic with respect to the platform coordinate. The periodicity depends on the feed speed of the platform. This problem is addressed by transforming the time domain system dynamics to the platform's coordinate frame. In the control scheme, a time varying model reference control is first designed to render a time invariant system. A repetitive control is then added to the compensated time invariant system to track periodic profiles.This paper presents the scheme's real time implementation and its experimental results.

Tip-Tilt Mechanism Controlled by an HBRISC2 Space Grade Processor,

E. Onillon, L. Lisowski, P. Spanoudakis, CSEM, Switzerland

E. Gilson, SABCA, Belgium

09:48—10:06

The CSEM, or Swiss Center of for Electronics and Microtechnology, has developed a Tip-Tilt mechanism based on a flexible guiding (Flextec) solution. This Tip Tilt mechanism allows three degrees of freedom, two angular ones and a translation one. A state space controller that takes into account coupling between the three degrees of freedom has been developed. This controller is to be implemented on an HBRISC2 space grade processor. The power electronic is based on a CSEM Intelligent Motion Control System (IMCS), developed to be used as a generic electronic front-end for complex mechatronics systems.

Automatic Control of Bicycles with a Balancer

M. Yamakita, A. Utano, Tokyo Inst. of Tech., Japan

10:06—10:24

In this paper, trajectory tracking and balancing control for autonomous bicycles with a balancer are discussed.In the proposed control method, an input-output linearization is applied for trajectory tracking control and a nonlinear stabilizing control is used for the balancing control. The control methods are designed independently first and their interference is compensated for later. The stability of the bicycles is ensured with the method even when the desired speed is zero. The effectiveness of the proposed method is shown by several numerical simulations using a detail model of a bicycle.

Line Map Construction Using a Mobile Robot with a Sonar Sensor

M. Jaradat, *R. Langari,* Texas A&M Univ., USA

10:24—10:42

The objective of this study is to present a way to construct a line map of an unknown indoor environment using a mobile robot equipped with a single sonar sensor. The proposed procedure consists of two main steps. In the first step, the sonar sensor measurements from the robot surroundings are mapped into a two-dimensional occupancy grid map. In the second step, the Radon Transform is used to extract the line parameters from the occupancy grid map. These parameters are subsequently used to represent the profiles of the detected objects as a representation of the robot environment. The presented experiments in this work have confirmed that the proposed line map construction approach is able to reconstruct the unknown indoor environment in spite of the uncertainty in sensor measurements.

WB1	Mobile Robot Systems		Tele-Operation	WB2
	Big Sur 1 (11:00—12:30)		Big Sur 2 (11:00—12:30)	
	Stefano Chiaverini, Italy	CHAIR	Wayne Book, USA	
	Mo-Yuen Chow, USA	CO-CHAIR	Toru Namerikawa, Japan	

The Null-Space-Based Behavioral Control for Soccer-Playing Mobile Robots

G. Antonelli, F. Arrichiello, S. Chiaverini, Univ. di Cassino, Italy

In this paper a behavior-based approach for the control of soccer-playing mobile robots is presented. The so-called Null-Space-Based (NSB) behavioral control differs from the other existing methods in the behavioral coordination, i.e., in the way the outputs of the single elementary behaviors are composed to yield a complex behavior. The developed approach is demonstrated in an experimental case study with a differential-drive mobile robot kicking a ball in a goal.

11:00—11:18

Passive Coordination of Nonlinear Bilateral Teleoperated Manipulators

M. McIntyre, Clemson U., *W. Dixon*, U. of Florida
D. Dawson, E. Tatlicioglu, Clemson U., USA

Significant research has been aimed at the development and control of teleoperator systems. Two controllers are developed in this paper for a nonlinear teleoperator system that targets coordination of the master and slave manipulators and passivity of the overall system. The first controller is proven to yield a semi-global asymptotic result in the presence of parametric uncertainty in the master and slave manipulator dynamic models. The second controller yields a global asymptotic result despite unmeasurable user and environmental input forces. Continuous nonlinear integral feedback terms are used to accommodate for incomplete system knowledge for both of the controllers. Lyapunov-based techniques are used to prove that all control objectives are met.

Controlling a Path-Tracking Unmanned Ground Vehicle with a Field-Programmable Analog Array

P. Dong, G. Bilbro, M. -Y. Chow, North Carolina State Univ., USA

Unmanned ground vehicle (UGV) path-tracking has been an important topic in Mechatronics real-time applications. This paper describes the implementation and performance of path-tracking UGV using a field programmable analog array (FPAA). The FPAA AN10E40 is a general-purpose, digitally reconfigurable analog chip. Its current commercial applications center on signal conditioning, base-band analog signal processing and rapid prototyping. This paper will show that the AN10E40 can also readily implement a control system for a path-tracking UGV. The FPAA controlled UGV made about 38% fewer tracking error with 22% faster traveling speed than a digital microcontroller (MC68HC11) controlled UGV.

11:18—11:36

Higher-Order Sliding Mode Impedance Bilateral Teleoperation with Robust State Estimation under Constant Unknown Time Delay

L. G. Garcia-Valdovinos, V. Parra-Vega, CINVESTAV-IPN
M. A. Arteaga, UNAM, Mexico

Time delay teleoperation systems have gained gradual acceptance due to technological advancements, in particular in its communication channel, however, it is difficult to measure in real time the time delay. In this scheme, slave teleoperators are in contact to rigid environments, wherein slave control requires fast, robust and free of chattering control, thus making first order sliding mode teleoperation control unsuitable. As an alternative, chattering free, higher-order sliding mode teleoperator control is proposed in this paper to guarantee robust tracking under constant, but unknown time delay.

Learning of Body Sense and Body Image for Mobile Robot with Visual Sensors

N. Sekiguchi, T. Tanaka, S. Kaneko, Hokkaido Univ., Japan

We propose self-maintenance robot system as a method which realizes work for a long time without maintenance by the human workers. This system absorbs the change which occurs in robot's hardware by learning, and maintains working ability. We use a neural network which has a task common layer and a task independence layer to learning. In this report, we verify of this learning system by the computer simulation and the experiment in the real field.

11:36—11:54

Robust Control of Master-Slave Robot System Considering Environmental Uncertainties

R. Lin, T. Namerikawa, Nagaoka Univ. of Tech., Japan

This paper deals with robust control of a master-slave teleoperation robotic system considering environmental uncertainties.
We construct a master-slave system by using two 2-DOF Direct Drive robot manipulators and design a robust control system via impedance shaping and Mu-Synthesis considering various uncertainties; e.g., environment and operator dynamics, perturbation of impedance model and time delay in telecommunications. The proposed control methodology can guarantee the robust stability and the robust performance for all these uncertainties of the master-slave robotic system. Several experimental results show the effectiveness of our proposed approach for various environmental uncertainties.

Human Machine Cooperative Tele-Driving System with Command Path Compensation Algorithm

Y. Kunii, M. Moriyama, S. Nagatsuka, Y. Ishimaru, Chuo Univ., Japan

In this paper, we discuss and evaluate our proposed human machine cooperative tele-drive system consisted of global and local path-planning, for a long range traversability. For corresponding to unknown obstacle, a conventional autonomous path-planning algorithm is applied between each waypoint. A rover is up-dating environment data, and then it causes the difference between terrain data used for commanding of an operator and for traversing of a rover. Therefore, we have to compensate path by using the latest measurement data which can be assumed more reliable than previous data. The difference is assumed as the distortion between each data set, and compensated by using a distortion compensation matrix.

11:54—12:12

Moving Average Based Adaptive Buffer for Haptic Media Synchronization in Telehaptics

O. Wongwirat, S. Ohara, Tokai Univ., Japan

Telehaptics is involved with remote surgery in teleoperation applications. The problem of telehaptics of this type is a delay variation on networks, or jitter delay. To solve the delay variation problem, a method of synchronization is required. This paper proposes the adaptive buffering control method for haptic media synchronization. The adaptive mechanism employs a moving average smoothing technique to calculate an expected delay in accordance with the delay variations resulting from the network traffics. Then, the expected delay is used to adjust the buffer size under a specified threshold. As the results, the proposed synchronization using the adaptive buffer approach can preservethe loss of haptic sequences better than the fixed buffer approcah under specified conditions.

Fuzzy Logic Self-Motion Planning and Robust Adaptive Control for Tip-Over Avoidance of Redundant Mobile Modular Manipulators

Y. Li, Y. Liu, Univ. of Macau, Macao SAR, China

A redundant nonholonomic mobile modular manipulator is investigated. Redundancy of the atop manipulator is used to avoid tipping over of the entire robot through automatically adjusting self-motions in a realtime manner. Based on modular robot concept, a kind of integrated dynamic modeling method is proposed. A realtime fuzzy logic self-motion planner and a robust adaptive controller are presented to prevent the robot from overturn without affecting the end-effector specified tasks. A new sliding mode function is devised, which is not only continuous but also infinitely differentiable. The proposed algorithm does not need a priori dynamic parameters and has strong external disturbance suppression ability.

12:12—12:30

A Robot Arm/Hand Teleoperation System with Telepresence and Shared Control

H. Hu, J. Li, Z. Xie, *B. Wang,* Harbin Inst. of Tech., China
H. Liu, G. Hirzinger, Inst. of Robotics and Mechatronics, DLR, Germany

This paper describes a master-slave teleoperation system which is developed to evaluate the effectiveness of teleopresence in telerobotics applications. The operator wears a dataglove augmented with an arm-grounded force feedback device to control the dexterous hand and utilizes a Spaceball to control robot arm. Contact forces measured by the finger sensors can be feedback to the operator and visual telepresence systems collect the remote operation scenes and display to the operator by a stereo helmet. A primitive autonomous grasp system based on parallel joint torque/position control is developed.

WB3	Software for Mechatronic Systems		Control Application in Mechatronics I	WB4
	Big Sur 3 (11:00–12:30)		Windjammer 1 (11:00–12:30)	
	Roland Siegwart, Switzerland	CHAIR	Cevat Gokcek, USA	
	Hiroshi Hashimoto, Japan	CO-CHAIR	Li-Chen Fu, Taiwan	

Distributed Collaborative Decision Support System for Rocket Launch Operation

S. Misono, S. Koide, N. Shimada, M. Kawamura, S. Nagano
Galaxy Express Corp., Japan

This paper presents an overview of a decision support system for rocket launch operation from the viewpoint of distributed collaboration mechanisms. The system comprises interface agents that mediate between operators on site or support engineers in distance and various Web Services that function as large-grain-size task modules for operation support. In order to orchestrate the distributed Web Services over the Internet, we have adopted Semantic Web Services technology that enables to compose the atomic Web Services in order to achieve the given goal. The interface agent for operation support is also a Web Service Agent that behaves that composes Web …

11:00–11:18

Resonance Seeking Control

C. Gokcek, Michigan State Univ., USA

An adaptive control method that seeks the unknown resonant frequency of a load and drives it at its resonant frequency to achieve optimal performance is proposed and investigated. The method is based on estimating the derivative of the average power with respect to the driving frequency and using this estimate to adaptively control the driving frequency. Assuming that the driving frequency is sufficiently large compared to the amplitude of sinusoidal perturbation, a nonlinear model that accurately predicts the performance of the resonance seeking control system is developed. This developed model is subsequently linearized to obtain a linear time-invariant model that facilitates both analysis and design. Guidelines for designing the resonance seeking control system are also provided.

Applications of a Real-Time Software Framework for Complex Mechatronic Systems

F. Pont, S. Kolski, R. Siegwart, Swiss Fed.l Inst. of Tech. Lausanne (EPFL), Switzerland

As the complexity of the missions to be performed by mechatronic systems grows, so does the amount of embedded software to be produced and the number of involved specialists. System complexity management and software integration become more important. In this paper, we present an initial implementation of a real-time capable software framework for complex mechatronic systems that facilitates embedded software development and integration. The framework also promotes software components reuse across applications, architecture reuse and software portability across hardware platforms. To illustrate the proposed solution, ….

11:18–11:36

A Dynamic Precedence Queue Mechanism to Assign Efficient Bandwidth in CAN Networks

H. S. Choi, *J. M. Lee,* Busan National Univ., Korea

This paper presents a distributed precedence queue mechanism to resolve unexpected transmission delay of a lower priority transaction in a CAN based system, which keeps a fixed priority in data transactions. The mechanism is implemented in the upper sub-layer of the data link layer (DLL), which is fully compatible with the original medium access control layer protocol of CAN. Thus the mechanism can be implemented dynamically while the data transactions are going on without any hardware modification. The proposed solution provides a superset of the CAN logical link layer control, which can coexist with the older CAN applications. Effectiveness of the proposed mechanism is verified by the real experiments.

Composite Component Framework for RT-Middleware

N. Ando, T. Suehiro, K. Kitagaki, T. Kotoku, *W. -K. Yoon*, National Inst. of Advanced Industrial Science and Tech., Japan

We have studied a framework of RT-Component which promotes application of Robot Technology (RT) in various field. In this paper, we will discuss robotic system development methodology and our RT-Middleware concepts. The system development methodology using RT-Component, and new framework to make composite component for RT-Component will be shown. A evaluation of composite component framework, which realizes low level and real-time composition of independent RT-Components, will be derived. Finally conclusion and future work will be described.

11:36–11:54

Disturbance-Observer-Based Repetitive Control with Sliding Modes

Y. -S. Lu, C. -M. Cheng, National Yunlin U. of Science and Tech., Taiwan

This paper proposes a sliding repetitive control (SRC) scheme based on sliding disturbance observers (SDOB) for repetitive tracking control tasks. The SDOB-based feedback compensation ensures acceptably small tracking error during initial learning trials and enhances system insensitivity to exceptional and aperiodic disturbances. The learning compensation is updated according to a switching signal that is equivalent to the error of the feedforward compensation, yielding fast convergence of the learning process from trial to trial. Because the switching actions to ensure global existence of a sliding mode take place in the controller instead of the plant, the proposed scheme thus alleviates the chatter problem often encountered in conventional sliding-mode controls.

A Generic Software Platform for Controlling Collaborative Robotic System Using XML-RPC

G. Glez. de Rivera, R. Ribalda, J. Colas, J. Garrido, EPS-Univ. Autónoma de Madrid, Spain

This paper describes a software platform used for controlling any set of collaborative robots. The platform is specially designed for users without special skills on hardware design or communication topics. The platform provides a standard to simplify the addition of new hardware devices. The system runs over Linux operating system; it is accessible through different programming languages. Calls among architecture processes are performed using XML-RPC. Data transport is TCP-IP based; therefore the system is accessible from a conventional Internet link. Some experiments are performed in order to detect the programming languages.

11:54–12:12

Task Skill Transfer of 3-Prong Plug Manipulation

W. -K. Yoon, T. Suehiro, H. Onda, K. Kitagaki, AIST, Japan

This paper describes how to write a task skill program for a 3-prong plug manipulation. One of important features in this paper is that it is easy to program a hole search motion and so on. In a previous paper, we proposed a task skill transfer method using a bilateral teleoperation. The task skill is composed of an initial condition, a task skill motion and a final condition. The task skill motion is implemented by the hybrid impedance/force control which is effective to a positional error. A motion process of the task skill is defined from the teleoperation procedure. The necessary parameters of the task skill are obtained from the results of teleoperation experiment. Thus, the task skill is generated from the teaching data and the teaching intention (motion strategy).

Image Training Assist System for Motor Skill Learning

K. Ishii, J. Hatayama, K. Seki, T. Kobayashi, H. Murakoshi, Tokyo Metropolitan Inst. of Tech., *H. Hashimoto*, Tokyo U. of Tech., Japan

We propose image training assist system for motor skill learning. The system consists of a monitor, cameras, sensors, and PCs. The system captures the learner's motion and displays the learner's motion by 3DCG in the virtual environment on the monitor. The learner can put down a point and comments in the virtual environment displayed by the monitor. Since the point is overlapped on the instructor's motion and displayed while learning, the learner can train the motor skill with the specified point. Moreover, the system provides effective functions for the motor skill learning such as the comparison between the learner's motion and the instructor's, the current and the past. We adapt the system to learning Kyudo (Japanese archery) as one of the motor skill learning.

12:12–12:30

Backstepping Controller Design for a Planar Maglev Positioning System

M. -Y. Chen, China Inst. of Tech.
S. -K. Hung, *L. -C. Fu,* National Taiwan U., Taiwan

In the previous research, an electro-magnetic actuator system has to be designed and implemented successfully. Based on those experiences, a prototype of a novel planar Maglev positioning system is designed in this research. In the new structure, the carrier motion (both levitation and propulsion) results from a sum of repelling forces each exerted on some magnet from its corresponding coil. Likewise, the associated full-DOF model is initially derived and analyzed, and then a backstepping controller for this Maglev positioning system is developed. Finally, from the experimental results, satisfactory performances including regulation, tracking accuracy and control stiffness.

WB5

Intelligent Process Automation

Windjammer 2-3 (11:00—12:30)

Jindong Tan, USA — CHAIR

Michael Branicky, USA — CO-CHAIR

MEMO

Localization for Robotic Assemblies Using Probing and Particle Filtering

S. Chhatpar, *M. Branicky*, Case Western Res. Univ., USA

This paper deals with robotic assemblies where position uncertainty exceeds assembly clearance. We focus on the assembly of a key in a lock, with lock-position uncertainty in (x,y,z). We implement a localization strategy that resolves uncertainty using a pre-acquired map of key-lock contact configurations. Using the key as a probe, the strategy explores the contact C-space at various positions matching those with the pre-acquired map. The strategy progressively localizes lock-position to achieve assembly. For computational efficiency, we use particle filtering, which can handle the discretization errors in map-matching and track multiple solutions simultaneously. The implementation was highly successful: uncertainty was reduced by more than 95% and 45 of 50 trials were successful.

11:00—11:18

Sintering Finish Point Intelligent Control

L. Peng, Z. Ji, Southern Yangtze U., China, *J. Tan*, Michigan Tech. U., USA

Sintering process is very important for blaster furnace production. This plant is a heavy nonlinear unknown object, the traditional control is hard to achieve good results. Traditional Adaptive pole placement method is effective in linear control system theory with an accurate linear model essentially. Its capability to overcome nonlinear disturbance is limited. The neural network identifier can set up an accurate model for an unknown nonlinear object. A neural network model with a special structure, which is divided into linear and nonlinear parts, is applied into identify an unknown nonlinear system object in this paper. The model identification speed and accuracy are improved.

11:18—11:36

Optimizing Material Distribution for Tool Trajectory Generation in Surface Manufacturing

H. Chen, N. Xi, Michigan State U., *W. Sheng,* Kettering U.
J. Dahl, Ford Motor Co., USA

Automatic CAD-guided tool planning has many applications in surface manufacturing, such as spray painting, spray forming and indirect rapid tooling. Generating tool trajectories for free-form surfaces to satisfy the given requirements is still highly challenging due to the complex geometry of free-form surfaces and the spray gun model. Because of the irregular shape of automotive parts, the spray width may not be a constant. Also the path integration for a part with multiple patches may need the spray width to be changed. This will increase the material distribution deviation. In this paper, algorithms are developed to minimize the material distribution deviation because ….

11:36—11:54

Intelligent Automated Negotiation Mechanism in E-Commerce

H. Zhang, Y. Qiu, Southwest China Normal Univ., China

Negotiation is an important function for e-commerce system to be efficient. However, negotiation is complicated, time-consuming and difficulty for participants to reach an agreement. This paper aims to establish an automated negotiation mechanism based on fuzzy method so as to alleviate the difficulty of negotiation.This automated negotiation is performed by antonymous agents that use fuzzy logic and issue-trading strategies in finding mutually-agreed contracts.The negotiation experiment setup between agents and humans, results shows that agents have the ability to replace humans in negotiation.

11:54—12:12

Development of an Integrated System for Setup Planning and Fixture Design in CAPP

Y. Zhang, G. Peng, Harbin Inst. of Tech., China

The separation of CAPP and CAFD often causes conflict and delays for the product development. This paper overcomes these obstacles by describing a developed system that is capable of carrying out setup planning and fixture design concurrently. An intelligent approach for setup planning is introduced. In this approach, the setups are automatically planned based on key factors of machining practice, tolerance requirement, manufacturing cost and fixturing constraints from the feedback of fixture design. Further more, a hybrid RBR and fuzzy evaluation method based automatic fixture design approach is also described. In proposed system, the feedback is to ensure that the setup plan for machined part is generated on the basis of feasible fixture plan.

12:12—12:30

WC1	Network-Based Mechatronics		Visual Servoing	WC2
	Big Sur 1 (14:00—15:12)		Big Sur 2 (14:00—15:12)	
	Mo-Yuen Chow, USA	CHAIR	Bruno Siciliano, Italy	
	Weihua Sheng, USA	CO-CHAIR	Winncy Du, USA	

Peer-To-Peer Multi-Robot Coordination Algorithms: Petri Net Based Analysis and Design

W. Sheng, Kettering Univ., USA, *Q. Yang*, Iteris Inc., USA

In this paper, a peer-to-peer coordination algorithm is developed to provide robustness to multi-robot missions, in the context of exploring unknown environments. The validation, analysis and design of the coordination algorithm require formal modeling methodologies. We propose a stochastic Petri net (SPN) based method to analyze and design efficient peer-to-peer coordination algorithms. By running the Petri net model, optimized parameters are obtained to improve the efficiency of the multirobot team. Peri Net simulation and algorithm implementation have validated the proposed algorithm.

14:00—14:18

An Experimental Setup for Visual Servoing Applications on an Industrial Robotic Cell

V. Lippiello, B. Siciliano, L. Villani, Univ. Napoli Federico II, Italy

An experimental setup for visual servoing applications on an industrial robotic cell is presented in this paper. The setup is composed of two industrial robot manipulators equipped with pneumatic grippers, a vision system and a belt conveyor. The original industrial robot controllers have been replaced by a single PC with software running under a real-time variant of the Linux operative system. A vision-oriented software environment named VESPRO has been developed on a PC running under Windows NT operating system, which allows programming image processing and visual tracking tasks, using one or more cameras. Advanced user interfaces permit fast, safe and reliable prototyping of control schemes based on visual measurements.

Intelligent Space with Time Sensitive Applications

W. -L. D. Leung, R. Vanijjirattikhan, Z. Li, L. Xu, T. Richards, B. Ayhan, M. -Y. Chow, North Carolina State Univ., USA

Intelligent Space (iSpace) is a relatively new concept to effectively use distributed sensors, actuators, robots, processors and information technology over communication networks. iSpace is a large scale Mechatronics System by integrating sensors, actuators and control algorithms in a communication system using knowledge from various engineering disciplines such as automation and control, hardware and software design, image processing, communication and networking. This paper describes a project "Johnny6 plays fetch in iSpace" to prototype an iSpace at North Carolina State University. The description includes hardware, software and networking algorithms used for this project.

14:18—14:36

Integrated Camera Motion Compensation by Real-Time Image Motion Tracking and Image Deconvolution

K. Janschek, V. Tchernykh, S. Dyblenko, Tech. Univ. Dresden, Germany

This paper presents the concept of a smart satellite pushbroom imaging system with internal compensation of attitude instability effects. The compensation is performed within the optical path by an active opto-mechatronic stabilization of the focal plane image motion in a closed loop system with visual feedback. Residual distortions are corrected by image deblurring through deconvolution. Both corrective actions are derived from a real-time image motion measurement which is based on an auxiliary matrix image sensor and an onboard optical correlator. The paper describes the principles of operation, the main system elements and gives detailed performance figures derived from a simulation performance model, which contains all relevant components of the smart imaging system.

Muscle-Like Control of Entertainment Robot Over Internet

K. Naruse, Univ. of Aizu, *M. Oya*, Hokkaido Univ., Japan

This paper proposes the combination of the Web services technology and the autonomous robot motion generation is the proper approach. For the motion generation, we introduce the muscle-like control method, which can be applied to any kinds of robots easily with proving a variety of creature-like motions. The method is applied to gait generation of a simulated four-legged robot, and the results show that it can transit from a motion to another one smoothly. In addition, the simulated robot is controlled by the Web services over Internet for investigating the feasibility of the proposed control scheme in a real network circumstance. The result shows that the proposed method provides us smooth control of the robot, even we have overhead of Web service processes and delayed communication.

14:36—14:54

Visual Servoing for Constrained Robots: A New Complete Theoretical Framework and Its Experimental Validation

E. C. Dean-León, L. G. Garcia-Valdovinos, V. Parra-Vega, CINVESTAV
A. Espinosa-Romero, UADY, Mexico

The theoretical framework and experimental validation of a new image-based position-force control is presented. This scheme produces convergence of the constrained visual position and the contact force between the end-effector and the constraint surface. Camera and robot parameters are considered uncertain. Furthermore, important problems of friction at the joint and contact point arise. Therefore, compensation of dynamic joint friction and viscous contact friction are also studied. In order to prove the effectiveness of the scheme, a Linux-RTAI OS experimental system is used to obtain a direct-drive robot manipulator equipped with a JR3 force sensor and a digital fixed camera.

Analysis of Delay and Traffic Load in Networked Control System

L. Yang, Y. Li, BeiHang Univ., China
G. Yang, Singapore Inst. of Manuf. Tech., Singapore

Time delay and delay jitter are the critical issues in system design of networked control systems (NCS). Aiming at the particularity of control network, the conceptions of loop-delay and network-delay are proposed in view of control and network, and their intentions, properties and acquiring methods are compared. The theoretical analysis and mathematic description about characteristic and evaluating index of network-delay are presented. Furthermore, the traffic load composition and estimating method are discussed. Taking the double-motors synchronization control system as an example, the simulation of corresponding NCS is implemented. The validity of above mentioned methods is verified.

14:54—15:12

Kalman Filter Design and Implementation for the 2D Real-Time Testbed Control Using EVS

W. Du, San Jose State U., *M. Gonzales,* Lockheed Martin Space Systems, USA

This paper addresses Kalman Filter implementation for a 2D spacecraft control using an EVS. Initial work revealed that the angle measured by the EVS was has a significant amount of noise. A 3-state Kalman filter was therefore designed and implemented to attenuate the vision data noise. The Filter model was derived and quantified. Simulation for nominal cases without external disturbance and simulation for the same noise level but apply a 0.015 N-m external disturbance torque were conducted and gave satisfactory results. Finally, the testbed closed-loop normal pointing performance and slew performance with the designed Kalman Filter were tested and evaluated. The results show that the system performances met the 0.25 degree RMS pointing requirement.

WC3	Sensor Plat. Enabling Multiple Modes of Mobility I		Control Applications in Mechatronics II	WC4
	Big Sur 3 (14:00—15:12)		Windjammer 1 (14:00—15:12)	
	Ravi Vaidyanathan, USA	CHAIR	Yangmin Li, Macau	
	Tom Huynh, USA	CO-CHAIR	Jangmyung Lee, Korea	

Design of an Autonomous Amphibious Robot for Surf Zone Operation: Part I Mechanical Design for Multi-Mode Mobility (I)

A. Boxerbaum, P. Werk, R. D. Quinn, Case Western Res. U.
R. Vaidyanathan, Naval Postgraduate School, USA

The capability of autonomous and semi-autonomous platforms to function in the shallow water surf zone is critical for a wide range of military and civilian operations. Of particular importance is the ability to transition between locomotion modes in aquatic and terrestrial settings. The study of animal locomotion mechanisms can provide specific inspiration to address these demands. In this work, we summarize on-going efforts to create an autonomous, highly mobile amphibious robot. A water-resistant amphibious prototype design, based on the biologically-inspired Whegs™ platform, has been completed.

14:00—14:18

Assembly Approach for Bimanual Robots

M. J. Hwang, KAIST, *S. Y. Chung*, Samsung Heave Industries
D. Y. Lee, Korea Advanced Inst. of Science and Tech., Korea

Bimanual, or two-handed, robots can be useful for assembly tasks in unstructured environment where it is difficult to have fixtures. The assembly is planned at the task-level with assembly models using contact states and their transitions. The lower-level velocity commands are automatically derived from the task-level symbolic transitions by solving constrained optimization problem formulated with assembly constraints and positions of the workpieces. The proposed approach is evaluated with simulation of the peg-in-hole assembly with an L-shape peg, that ordinary position control scheme cannot complete.

Design of an Autonomous Amphibious Robot for Surf Zone Operations: Part II - Hardware, Control Implementation and Simulation (I)

R. Harkins, J. Ward, R. Vaidyanathan, Naval Postgraduate School
A. S. Boxerbaum, R. D. Quinn, Case Western Res. Univ., USA

This paper describes on-going work at The Naval Postgraduate School (NPS) and Case Western Reserve University (CWRU) to create an autonomous highly mobile amphibious robot. A first generation land-based prototype has been constructed and field tested. This robot design, based on a tracked element, is capable of autonomous waypoint navigation, self orientation, obstacle avoidance, and has the capacity to transmit sensor (visual) feedback. A water-resistant second generation amphibious prototype design, based around the biologically inspired Whegs platform, has been completed. This design marries the unprecedented mobility of WhegsTM with …

14:18—14:36

Fast-Motion Trajectory Generation for a New Direct-Drive Planar Parallel Manipulator

Y. Liu, L. Sun, D. Jie, Z. An, *H. Cai,* Harbin Inst. of Tech., China

A new direct-drive planar parallel robotic manipulator is presented for fast-motion positioning. Because of nonlinearity of kinematics and dynamics, the achievable maximum velocity and maximum acceleration vary at different points and directions. To make the manipulator move with fully high velocity and high acceleration along the specified trajectory, a fast-motion trajectory generation technique is introduced. Given limitations on speed and torque of the actuators, the available values of maximum velocity and maximum acceleration along the specified trajectory are firstly derived, and then several motion profiles are generated. Finally, the experiments of trajectory generation are conducted on the manipulator.

A Robot Designed for Walking and Climbing Based on Abstracted Cockroach Locomotion Mechanisms (I)

T. Wei, R. D. Quinn, R. E. Ritzmann, Case Western Res. Univ., USA

MechaRoach II is a hexapod robot under development that will test strategies for transitioning between the two. The locomotion principles that allow cockroaches to make these transitions have been studied and mechanisms using abstractions of those principles have been developed for the robot. These principles include usage of features of leg and foot morphology, leg compliance, gait adaptation, and body flexion. MechaRoach II has a single drive motor, a motor for steering, and a motor to actuate a body flexion joint. The single drive motor powers all six legs, and each leg uses 4-bar mechanisms to recreate cockroach-like foot trajectories. The robot normally walks in a tripod gait, but uses passive torsionally compliant devices.

14:36—14:54

Leader-Formation Navigation Using Dynamic Formation Pattern

X. Chen, *Y. Li,* Univ. of Macau, Macao SAR, China

Formation navigation is an interesting topic in robotic community. In this paper, we focus on two aspects of formation navigation, leader-formation keeping and obstacle avoidance. A local control strategy based on adaptive NN control with robust term and a general obstacle avoidance strategy are proposed. It is proved that if formation pattern is smooth continuous, even interaction topology is dynamic, the robots using the local control strategy must form the formation determined by formation pattern. Applying dynamic formation pattern, a simulation illustrates formation navigation within an obstacle field where there exist two kinds of obstacles.

A Multi-Sensory Robot for Testing Biologically-Inspired Odor Plume Tracking Strategies (I)

J. Bailey, M. Willis, R. D. Quinn, Case Western Res. Univ., USA

Many animals routinely locate environmental resources by tracking the chemical plumes they release. A robot able to match the performance of these biological examples would provide a reliable method for locating sources of turbulently dispersed chemicals. Working towards this goal, a suitable sensor suite was interfaced to a mobile robot. Wind sensors were developed and integrated on the platform with chemical sensors. The robot autonomously orients to wind and moves upwind similar to animals that are following a plume. In future work the robot will be used to test odor tracking algorithms inspired by the hawkmoth Manduca sexta.

14:54—15:12

Stability Analysis and Control of Overhead Crane with Time-Dependent Flexible Cable

K. Moustafa, United Arab Emirates Univ., UAE
M. Trabia, U. of Nevada at Las Vegas, USA, *M. Ismail*, Zagazig Univ., Egypt

A mathematical model of an overhead crane system with load hoisting and a flexible cable is presented. The model consists of a hyperbolic partial differential equation describing the dynamics of the moving flexible cable and ordinary differential equations describing the trolley and payload dynamics. Lyapunov direct method is used to design a model-based boundary control law that achieves trolley and payload desired positions and ensures vibration reduction of the flexible cable. The proposed control law is based on measurable variables for the trolley and the cable. The stability of the closed loop system under this boundary control scheme is proved through the use of inequality and metric analysis.

WC5

Robot Control

Windjammer 2-3 (14:00—15:12)

Aiguo Ming, Japan — CHAIR

Tao Ming Lim, Singapore — CO-CHAIR

MEMO

An Application of Nonlinear Receding Horizon Control to Posture Control with Collisions — 14:00—14:18

M. Yamakita, A. Taura, Y. Onodera, Tokyo Inst. of Tech., Japan

In this paper, an extension of nonlinear receding horizon control (RHC) or model predictive control (MPC) for switched systems with state discontinuity is proposed based on continuation method and GMRES method and it is applied for a posture control with a collision. The validity of the method is demonstrated by a numerical simulation and an experiment.

Balancing 3D Objects with Rolling Constraint by Redundant Manipulator — 14:18—14:36

S. M. Yesiloglu, H. Temeltas, Istanbul Tech. U., *O. Kaynak*, Bogazici U., Turkey

A novel methodology is presented for a practical problem of balancing a round object about its contact point posing pure rolling constraint at the tip of a redundant manipulator. Two-layer controller, the objective of the first of which is to balance the object as long as the manipulator stays in a singularity-free predefined task-space, is designed. At the second layer, the contact point of the balanced object is aimed at repositioning at a close neighborhood of an, also predefined, conceptual center of task space. We call this transition a dynamic balance. In order to achieve the dynamic balance, one needs to disturb the static balance in a controlled manner. We, then, introduce the concept of an equilibria cone formed by the collection of static and dynamic equilibria.

A New Motion Control Method for Golf Swing Robot Hitting a Ball — 14:36—14:54

A. Ming, M. Henmi, C. Xu, M. Shimojo, U. of Electro-Communications, Japan

A new golf swing robot to simulate human motion has been developed. This paper deals with motion control of the robot for hitting a ball. For the case, it becomes important to control the motion of the robot after the impact, to avoid breaking a club. In this paper, a method for controlling the robot adaptable to various impact conditions is proposed. The motion state of the robot is estimated first by an extended Kalman filter, and a new reference trajectory is generated on-line according to the estimated state. The method has been implemented to the robot successfully.

Unified Force and Motion Control Using an Open System Real-Time Architecture on a 7 DOF PA-10 Robot — 14:54—15:12

T. M. Lim, SIMTech, *Q. H. Xia, M. Ang*, National U. of Singapore, *S. Y. Lim*, SIMTech, Singapore

The operational space formulation provides a framework for the analysis and control of robotic systems with respect to interactions with their environments. Using the modified PA-10, we implemented unified force and motion control to achieve force and position tracking. Impact control algorithm was also implemented to remove oscillation when the end-effector comes into contact with a stiff environment. The control algorithm uses a PC to perform the required real-time computation. With the modifications to the PA-10 controller, we are able to achieve high sampling rates with minimum communication latency. Software architecture was also developed to achieve software modularity.

WD1	Navigation of Mobile Robots		Industrial Vision	WD2
	Big Sur 1 (15:30—16:42)		Big Sur 2 (15:30—16:42)	
	Yoshio Yamamoto, Japan	CHAIR	Winncy Du, USA	
	Yan Meng, USA	CO-CHAIR		

A Scalable Graph Model and Coordination Algorithms for Multi-Robot Systems

J. Tan, Michigan Tech. Univ., USA

This paper presents a distributed model and the orresponding control algorithms for the cooperation and redeployment of mobile sensor networks. A mobile sensor network composes of a collection of wireless connected mobile robots equipped with a variety of sensors. The system can be rapidly deployed to hostile environment, inaccessible terrains or disaster relief operations. The mobile sensor network is essentially a cooperative multi-robot system. Delaunay Triangulation (DT) is used to define the geometrical relationship between neighboring sensor nodes. Based on this distributed model, this paper discusses a fault tolerant algorithm for autonomous self-deployment of the mobile robots.

15:30—15:48

A Normalization Based Image Affine Estimation Techniques for Computer Vision

H. I. Kang, S. Lim, K. I. Kim, Y. I. Son, Myongji Univ., Korea

In this paper, we propose the estimation method for the image affine information for computer vision. The first estimation method is given based on the XYS image normalization and the second estimation method is based on the XSR image normalization. In addition, we show that rotation and aspect ratio information can be obtained using the central moments of both the original image and the sensed image. Finally, we propose the modified version of the normalization method so that we may control the size of the image. It turns out that the XYS method has much better performance than the XSR method for the image having the aspect ratio change.

Online Dead-Lock Avoidance Scheme of Wheeled Mobile Robot under the Presence of Boxlike Obstacles,

Y. -C. Chang, Y. Yamamoto, Tokai Univ., Japan

This paper presents a path planner for the design of autonomous vehicles such as mobile robots. The path planner is based on the potential field method. Through the hough transformation the obstacle detection is accomplished by laser scanner. The local minima problem has been solved by redefining the repulsive potential field. Also the system controller (Look-ahead Control) gives the robot the capability of controlling the distance between the reference point and the center of the robot. As a result, the potential field method performs effectively under our system and allows the mobile robot follow a smooth trajectory in a flexible manner for attaining the desired goal autonomously whether in a static or dynamic environment.

15:48—16:06

Development of an Automatic Optical Measurement System for Automotive Part Surface Inspection

Q. Shi, N. Xi, Michigan State Univ., *Y. Chen*, FORD Motor Company, USA

This paper introduces an automated 3D optical measurement system. In industrial inspection, Coordinate Measurement Machines (CMMs) provide accurate measurement but are very time consuming because only one point can be acquired each time. An area sensor based robotic 3D measurement system can acquire an automotive part's surface patch-by-patch, which reduces the inspection time significantly. This paper describes a pixel-to-pixel sensor calibration scheme and a bounding box based sensor planning method which are developed for the automatic optical measurement system of large and complex surfaces. Experiment results are presented and discussed.

A Dynamic Self-Reconfigurable Mobile Robot Navigation System

Y. Meng, Stevens Inst. of Tech., USA

A mobile robot navigation system must adapt to the highly dynamic environments and emergencies under the real-time constraints. Sometimes some sensors may not work well with new environments while others may need to swap in at runtime to continue the navigation. This paper presents an agent-based embedded system platform which can dynamically reconfigure the robot system on the fly by integrating FPGA hardware and high-performance microprocessors system. Several dynamic reconfiguration models are described to improve the system efficiency with low reconfiguration latency. The reconfiguration architecture specifically for vision system is also presented. This platform can be easily extended to other robot systems, such as server robots, space robots, and multi-robot systems.

16:06—16:24

A Multi-Scale Focus Pseudo Omni-Directional Robot Vision System with Intelligent Image Grabbers

Q. Zhou, K. Yuan, W. Zou, P. Lu, Chinese Acad. of Sciences, China
H. Hu, Univ. of Essex, UK

In this paper, the development of an intelligent image grabber and its application to a multi-scale focus pseudo omni-directional robot vision system is presented. The new developed intelligent image grabber is designed using DSP and FPGA technology, which can do both the task of image grabbing and the task of image processing. A pseudo omni-directional robot vision system, which can "see" the four directions simultaneously using 4 sets of intelligent image grabbers and cameras, is realized and a multi-scale focus strategy which can improve the efficiency of this pseudo omni-direction robot vision system is also proposed. Experimental results show good agreement.

Design of Transport Mobile Robot Behavior in Self-Organizing Assembly System

A. Lazinica, B. Katalinic, Vienna Univ. of Tech., Austria

Bionic Assembly System is a concept of self-organizing assembly system which basic elements are autonomous mobile robots. The basic characteristics of the system are self-organization, adaptation and reconfiguration. This paper is focused on transport mobile robot type in the system and the simulation of robot's navigation in Webots software is presented. Transport mobile robot should be designed to navigate with collision avoidance capability in the shop floor environment, flexibly coping with the changing environment.

16:24—16:42

WD3	Sensor Plat. Enabling Multiple Modes of Mobility II		Vibration and Noise Control	WD4
	Big Sur 3 (15:30—16:42)		Windjammer 1 (15:30—16:42)	
	Roger D. Quinn, USA	CHAIR	Eric Maslen, USA	
	Ravi Vaidyanathan, USA	CO-CHAIR	Makoto Iwasaki, Japan	

A Robot with Cockroach Inspired Actuation and Control (I)
J. -U. Choi, B. L. Rutter, Case Western Res. U., *D. A. Kingsley*, Sarcos
R. E. Ritzmann, R. D. Quinn, Case Western Res. U. , USA

Robot V has been constructed with inspiration from the death head cockroach, Blaberus discoidalis. Its relative leg segment lengths, joint degrees of freedom, exoskeleton structure, relatively light legs, and location of its center of mass are all similar to those of the cockroach. In an attempt to take further advantage of the neuromechanics of the animal, actuators with muscle-like properties have been employed. The robot's controller includes biologically inspired gait generation and inverse kinematics components. An actuator tensioning reflex which approximates the function of muscle tone is introduced, and resulting improvements to system response are shown.

15:30—15:48

Experimental Verification of Stability Analysis of Closed-Loop Signal Shaping Controllers
J. Huey, W. Singhose, Georgia Inst. of Tech., USA

Input shaping is a vibration control technique that operates by filtering reference commands so that the modified command does not excite the system's natural frequencies. Usually, input shaping is implemented as a filtering operation outside of any feedback loops. However, this prevents input shaping from effecting some vital control issues including disturbance rejection, initial condition response, etc. Therefore, some research has studied the use of input shapers within feedback loops. This paper will present some investigations toward the fundamental understanding of how input shapers utilized within feedback loops affect stability. Experimental results on a crane illustrate the key results.

Behavioral Feedback As a Catalyst for Emergence in Multi-Agent Systems
D. W. Palmer, M. Kirschenbaum, L. Seiter, J. Shifflet, *P. Kovacina,*
John Carroll Univ., USA

Swarm algorithms rely on randomness to produce solutions for complex problems. The random selection of actions and chance interactions of agents force a swarm to attempt many behavioral possibilities -- reinforcing the productive ones and dampening the dead ends. Randomness however, is a dual-edged sword: it is necessary to insure a wide range of agent behavior, but also a source of inefficiency and wasted resources. Using behavioral feedback, we reinforce effective use of randomness -- using it to select from a restricted list of useful actions. By observing an agent's behavior over the three domains of time, space, or category, we establish a context for the application of randomness.

15:48—16:06

Robust Time-Optimal Command Shaping for Velocity Tracking of Piezoelectric Actuators
Y. Xu, P. H. Meckl, Purdue Univ., USA

This paper introduces a robust time-optimal command shaping technique for the application of piezoelectric actuators on scanning tunneling microscopy (STM). Though feedback control has been widely used to improve the linearity, the maximum scan rate is substantially limited by the turnaround transients in the scan path. Therefore, feedforward approach is considered to improve the scan speed. In the authors' earlier work, a robust input design method was proposed for a general class of systems without rigid-body mode. When this method is applied to velocity tracking, however, unique problems arise. This paper proposes a solution to these problems by modifying the sufficient condition in the frequency domain for robust inputs of velocity tracking, and the search procedure.

Utility of a Sensor Platform Capable of Aerial and Terrestrial Locomotion
R. J. Bachmann, BioRobots, LLC, *F. Boria, P. Ifju,* U. of Florida
R. D. Quinn, Case Western Res. U., *J. Kline, R. Vaidyanathan*,
Naval Postgraduate School, USA

Homeland security and national defense include many missions that would be served by a multi-sensor platform capable of flying, landing, perching, and walking. Soldiers in an urban environment could obtain near- and medium-field intelligence. Maritime personnel would benefit from a small aerial vehicle that could 'perch on' (hang from) the high point of a cargo ship during interdiction operations. The surveillance capabilities of unmanned aerial vehicles would be enhanced by a steatlthy vehicle able to gain closer approach to the target. Long term surveillance could be performed by a vehicle capable of flying, walking, and taking off from the ground.

16:06—16:24

Input Shaping for Continuum Beams under Longitudinal Vibration
J. Fortgang, W. Singhose, Georgia Inst. of Tech., USA

The applicability of standard input shapers to continuum longitudinal beams is presented in this paper. The effectiveness of different input shapers, specifically the Zero Vibration, the Zero Vibration and Derivative, and the Unity Magnitude-Zero Vibration shapers, is investigated. Also, the sensitivity of these schemes to modelling errors is presented. Through a derivation of the equation of motion of a longitudinal beam, single mode shapers are shown to have the same vibration reducing characteristics for the first mode of continuum systems as they do for lumped parameter systems. However, the contribution of higher modes is also shown to impact the response, especially when negative input shapers are employed.

16:24—16:42

Residual Vibration Suppression in Repetitive Positioning by Practical Initial Value Compensation
M. Iwasaki, M. Kawafuku, H. Hirai, Nagoya Inst. of Tech., Japan

This paper presents a novel residual vibration suppression methodology for the repetitive fast-response and high-precision positioning in machine tool drives. In sequential positioning motions, as the interval period of position references becomes shorter, the residual vibration in response due to undesired initial values deteriorates the positioning accuracy, since the positioning controller is generally designed on the condition that initial state variables are zero. In this research, an Initial Value Compensation (IVC) approach is proposed under the theoretical study on effects of the initial values on the position transient response. The IVC can appropriately assign poles and zeros of the transfer characteristic of position output for the initial values by applying an additional input.

WD5

Adpative Control

Windjammer 2-3 (15:30—16:42)

Bin Yao, USA — CHAIR

Kazuya Sato, Japan — CO-CHAIR

MEMO

Adaptive H-Infinity Control for Linear Slider with Friction Compensation Using Gradient Algorithms with Projection

K. Sato, Saga U., *K. Tsuruta*, Kyushu Sangyo U., *A. Shoji*, Saga U., Japan

15:30—15:48

In this paper an adaptive tracking control of a servo mechanism with friction is developed, based on notion of H-infinity optimality. It is assumed that the friction dynamics can be described by the LuGre model. The nonlinear characteristic function of the LuGre model is parameterized by Neural-Network (NN). The friction parameters are updated by estimating strategy in this proposed method. To cope with the practical applications., gradient algorithms with projection method is also applied to the unknown parameter estimation methods. Effectiveness of the proposed method is evaluated via some experimental results.

Robust Adaptive Control of Quasi-LPV Systems

X. Wei, L. Del Re, Johannes Kepler Univ., *J. Tan*, Michigan Tech. Univ., USA

15:48—16:06

In this paper a robust adaptive pole placement method for a class of linear parameter varying (LPV) system based on input-output description is constructed after the LPV system model, including its un-modeled error model term, is presented. The recursive least square estimation algorithm with dead zone is applied for the parameter estimation. The robust stability of closed-loop system is analyzed and the robust bound is derived. One simulation example illustrates the effectiveness of the control algorithm and demonstrates that the adaptive control based on LPV model can achieve better performance than the controller based on linear time varying (LTV) model.

A Globally Stable High Performance Adaptive Robust Control Algorithm with Input Saturation for Precision Motion Control of Linear Motor Drive System

Y. Hong, B. Yao, Purdue Univ., USA

16:06—16:24

This paper focuses on the synthesis of nonlinear adaptive robust controller with saturated actuator authority for a linear motor drive system, which is subject to parametric uncertainties, unmodeled nonlinearities and input disturbances as well. Global stability is achieved by breaking down the overall uncertainties to state-linearly-dependent uncertainties (such as viscous friction) and bounded nonlinearities (such as coulomb friction, cogging force and etc.) and treating them with different strategies. Furthermore, a guaranteed transient performance and final tracking accuracy can be obtained by incorporating the well-developed adaptive robust controller.

Adaptive Nonlinear Contour Coupling Control for a Machine Tool System

J. Lee, W. Dixon, J. Ziegert, C. Makkar, Univ. of Florida, USA

16:24—16:42

The quality of products from a machine tool system is largely determined by the tolerances maintained, which is a function of how well the desired contour is tracked. To mitigate contour errors in a three axis machine tool feed drive system, the control development in this paper is based on an error system that is transformed into tangential, normal and binormal components to the desired contour (i.e., a cross coupling controller (CCC)). Unlike previous CCCs, the first controller in this paper does not assume exact knowledge of the inertia and friction matrices. Specifically, an adaptive estimate is developed to compensate for uncertain friction and inertial parameters. Lyapunov-based methods are used to craft the adaptive estimate and to prove global asymptotic contour tracking.

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