### Principal Results (not more than 2 pages)

AMC 2012, held in Sarajevo, March 25-27, 2012, is the 12th in a series of biennial workshops that bring together researchers active in the advanced motion control field to discuss current development and future perspectives in motion control technologies. The goal of AMC 2012 is to provide a forum for relevant information exchange and promote environment for engineers and researchers to engage in fruitful discussions on different subjects. AMC 2012 is sponsored by IEEE IES and University of Sarajevo. Technical cosponsors are Sabanci University, IEEJ and SICE. The 187 papers are submitted for review, 113 papers accepted and presented at Workshop along with two plenary sessions and one round table. We did not have “no-show” at conference. Workshop program is shown below.

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Session</th>
<th>Session Title</th>
<th>Room</th>
</tr>
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<tbody>
<tr>
<td>25th March</td>
<td>14:30-15:15</td>
<td>PS-1</td>
<td>Plenary Session I</td>
<td>Room 1: Banjaluka</td>
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<td>15:30-17:30</td>
<td>OS-3</td>
<td>Compliant Locomotion Manipulation and Actuation</td>
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<td>Room 3: Sarajevo I</td>
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<td>10:00-12:00</td>
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<td>Haptics for Human Support</td>
<td>Room 1: Banjaluka</td>
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<tr>
<td>10:00-12:00</td>
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<td>10:00-12:00</td>
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<tr>
<td>13:00-15:00</td>
<td>OS-6-1</td>
<td>Musculoskeletal Structure based Robotics</td>
<td>Room 3: Sarajevo II</td>
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<td>CO-2</td>
<td>Control II</td>
<td>Room 4: Sarajevo III</td>
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<td>HR-2</td>
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<td>RO-2</td>
<td>Robotics II</td>
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</table>

The attendees come from 21 countries.

Post-conference publications:
Special section in Automatika, Zagreb (12 papers),
IEEE Trans on Industrial Electronics (planned 12 papers)
IEEE Transaction on Industrial Informatics (planned 12 papers).
Expected time of publication is 1st - 2nd quarter 2013.

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**Final Budget Statement**


The Sabancı University funds have been used as a loan and total amount of 7500TL is paid back to university.

**Publications or manuscripts prepared (one copy of any subsequent publication will be furnished to the URC)**

The program USB proceedings and the Book of abstracts are available at the time. The papers are copyrighted to IEEE and could be reached on IEEE Xplore.

**Signature of Principal Investigator**

Asif Şabanoviç

**Date**

July 19, 2012
ABSTRACTS

AMC 2012
The 12th International Workshop on Advanced Motion Control

Bristol Hotel, Sarajevo, Bosnia and Herzegovina
25-27 March 2012

Sponsored by the
IEEE Industrial Electronics Society and the University of Sarajevo

Technically Sponsored by
Welcome Message

It is our great pleasure to welcome you to IEEE AMC 2012 and Sarajevo. AMC 2012 is the 12th in a series of biennial workshops that bring together researchers active in the advanced motion control field to discuss current development and future perspectives in motion control technologies. The goal of AMC 2012 is to provide a forum for relevant information exchange and promote environment for engineers and researchers to engage in fruitful discussions on different subjects.

This year AMC is held in Sarajevo, a beautiful city with long and sometimes troubled history. We hope that everyone will find something interesting in Sarajevo, a city with long and rich history of the diversity and the coexistence of different religions, which attracted international attention several times throughout its history. It was the site of the assassination that sparked World War I, while seventy years later it becomes the host city of the 1984 Winter Olympics. More recently, Sarajevo underwent the longest siege in modern history. We hope that you will find some time to enjoy the city and hospitality of its people.

We would like to take this opportunity to thank our sponsors, IEEE Industrial Electronics Society and the University of Sarajevo. We are thankful to Sabancı University, which as technical co-sponsor of the workshop, supported all our efforts. We would like also to thank all our committee members, both local and international, our keynote speakers, all our track and session chairs and all authors. Our special thank goes to the special sessions organizers and our students both from EE Department of University of Sarajevo and Mechatronics program at Sabancı University, that have done and continue to do and incredible job for this workshop.

The papers to be presented cover many various topics related to advanced motion control, thus giving opportunity to scientists and engineers to talk through disciplinary boundaries.

Preparing for AMC 2012 was a memorable experience for us. We hope that it will become a memorable event for all of you.

Asif Šabanović and Kouhei Ohnishi
AMC 2012 General Co-Chairs
AMC 2012 Organizing Committee

General Co-Chairs
Asif Šabanović  
Sabanci University, Turkey
Kouhei Ohnishi  
Keio University, Japan

Program Co-Chairs
Toshiaki Tsuji  
Saitama University, Japan
Seta Boğosyan  
Alaska University-Fairbanks USA
Roberto Oboe  
Universita di Padova, Italy

Publicity Co-Chairs
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Nagoya Inst of Tech, Japan
William Messner  
Carnegie Mellon Univ., USA
Peter Korondi  
Budapest Univ. of Tech. and Economics, Hungary

Tresurers
Kemalettin Erbatur  
Sabanci University, Turkey

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Masayoshi Tomizuka, USA
Giuseppe Buja, Italy
Tosio Fukuda, Japan
Yoichi Hori, Japan
John Hung, USA
Karel Jezernik, Slovenia
Atsuo Kawamura, Japan

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Toshiyuki Murakami, Japan
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Hiroshi Fujimoto, Japan
Yasutaka Fujimoto, Japan
Zdenko Kovacevic, Croatia
Ivan Pertovic, Croatia
Masaaki Shibata, Japan
Seiichiro Katsura, Japan
Tomoyuki Shimono, Japan
Narcis Behlilovic, BiH
Kemalettin Erbatur, Turkey
Kenji Natori, Japan
Satoru Takahashi, Japan
Akira Shimada, Japan
Seiji Hashimoto, Japan
Mustafa Unel, Turkey
Metin Gokasan, Turkey

Local Organizing Committee
Narcis Behlilović
Elma Avdić
Dženita Sipović-Šabanadzovic
AMC 2012 Sessions Organizers

OS-1: Haptics for Human Support
Kiyoshi Ohishi (Nagaoka Univ. of Technology, Japan),
Seiichiro Katsura (Keio University, Japan),
Tomoyuki Shimono (Yokohama National University, Japan)

OS-2: Smart Precise Motion Control - Controller design for precision motion control
Makoto Iwasaki (Nagoya Inst of Tech, Japan),
Hirosi Fujimoto (The Tokyo Univ, Japan),
Roberto Oboe (Univ Padova, Italy)

OS – 3: Compliant Locomotion Manipulation and Actuation
Yasutaka Fujimoto (Yokohama National University, Japan),
Barkan Ugurlu (Toyota Technological Institute, Japan)

OS - 4: Network-based Control
Yutaka Uchimura (Shibaura Institute of Technology, Japan),
Kenji Natori (Aoyama Gakuin University, Japan)

OS – 5: Advanced Sensing, Estimation and Its Applications
(This session is jointly organized by IEEE/IES Sensors and Actuators Technical Committee and IEEJ ISAM Committee)
Naoki Oda (Chitose Institute of Science and Technology, Japan),
Toshiyuki Murakami (Keio University, Japan),
Kiyoshi Ohishi (Nagaoka University of Technology, Japan),
Seiichiro Katsura (Keio University, Japan),

OS-6: Musculoskeletal Structure based Robotics
Sehoon Oh (The University of Tokyo, Japan),
Toshiaki Tsuji (Saitama University, Japan)
General Information

Conference venue  HOTEL Bristol
Fra Filipa Lastrica 2,
71000 Sarajevo
tel: +387 33 705 000, fax: +387 33 705 001

Airport  Sarajevo International Airport
Information desk  tel: +38733289 100
http://www.sarajevo-airport.ba/?lang=eng
The taxi from the Sarajevo Airport (SJJ Sarajevo Intl.) should cost approximately 10EUR

Time Zone: Bosnia and Herzegovina and Sarajevo are in the Central European Time Zone (GMT + 1 hour).

Climate: Continental - warm summers and cold winters. Average temperature in Sarajevo during the Conference should be in the range 2-12 degree of Celsius.

Currency: The official currency is Convertible Mark (KM, Currency code is BAM); (1, 9558 BAM = 1 Euro). Currency exchange services are provided at:
- Banks, (the closest banks are just across the street of the hotel)
- Post offices

Public transportation:
The public transport system in Sarajevo are the tram and the buses. The tram station is very close to hotel. The one way ticket for an inner-city zone is 1.6KM if you purchase it in a kiosk, but if you buy ticket from driver price it is 1.8KM. The ticket must be punched as soon as you enter the vehicle. Failure to do so will result in the fine on the spot Tram station named POFALIĆI (trams No.2 and trams No.3) is close to Bristol Hotel

Taxi:
Sarajevo Taxi has one of the cheapest Taxi services in Europe. Sarajevo private Taxi companies operate in the city 24 hours a day. Taxi stands are clearly marked. Start rate is 1.6KM. Price for 2-3 persons, for transportation within the city, often is cheaper then using tram.

Important phone numbers
Police - 122
Firefighters - 123
First Aid – 124 (or 61 11 11)

Taxi:
Sarajevo Taxi: 1515 or 66 06 66
Zuti Taxi: 66 35 55 or 65 73 07
Crveni Taxi: 76 06 00 or 46 87 28

Insurance
Participants of Conference are advised to take out their own insurance in case of emergency illness or lost baggage.

Power Supply
-Voltage  220V AC, 50 Hz

Water
The water supply system in the city delivers clear and drinkable water.
**Social Events**

**Sunday, 25 of March 2012:**

**Welcome reception** will be held in Hotel Bristol (Conference venue) from 17:30 to 19:00

**Monday, 26 of March 2012:**

**Banquet** from 19:00 to 22:30. Additional tickets (Fee: 50 USD) for the banquet can be found on the Registration desk during registration.

Transportation from Hotel Bristol will be organized by shuttle bus at 18:30.

**Tourist events:**

During the Conference will be organized:

1) **Old town tour** (Sarajevo-European Jerusalem). The tour lasts about 3 hours and will be organized several times if necessary (Minimum 5 interested people is required).

2) **28 of March a full day trip** to Mostar will be organized if there are enough participants (canyon of the Neretva River and Mostar-UNESCO heritage city). Detail information on the tour is available at the registration desk (Minimum 15 people is required for the trip to be realized).

**Registration:**

**Sunday, 25th March** from 12:00 – 17:30

**Monday, 26th March** from 08:15 – 17:30

**Tuesday, 27th March** from 08:15 – 15:30
## AMC 2012 at a Glance

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<thead>
<tr>
<th>Time</th>
<th>Sunday, 25th March</th>
<th>Room 1- Banjaluka</th>
<th>Room 2-Sarajevo I</th>
<th>Room 3 – Sarajevo II</th>
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<tbody>
<tr>
<td>14:00-14:30</td>
<td>Opening Ceremony</td>
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<tr>
<td>14:30-15:15</td>
<td>Prof. Takahiro Yakoh</td>
<td>Uncertainty Principle in Real-Time Communication - Battle of Quickness against Correctness in NBCS-</td>
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<td>15:15-15:30</td>
<td>Coffee Break</td>
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<tr>
<td>15:30-17:30</td>
<td>OS - 3</td>
<td>OS-4</td>
<td>CO - 1</td>
<td>Control I</td>
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<td></td>
<td>Compliant Locomotion Manipulation and Actuation</td>
<td>Network-based Control</td>
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<tr>
<td>17:30-19:00</td>
<td>Welcome Party - Bristol</td>
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<tr>
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<th>Room 2-Sarajevo I</th>
<th>Room 3 – Sarajevo II</th>
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<tbody>
<tr>
<td>8:45-9:30</td>
<td>Prof. Fumio Harashima and Dr. Satoshi Suzuki</td>
<td>Human Adaptive Mechatronics and Human-System Modeling</td>
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<td>9:30-10:00</td>
<td>Coffee Break</td>
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<tr>
<td>10:00-12:00</td>
<td>OS-1-1</td>
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<td>Advanced Sensing, Estimation and Its Applications</td>
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<td>Haptics for Human Support</td>
<td>Smart Precise Motion Control</td>
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<tr>
<td>12:00-13:00</td>
<td>Lunch</td>
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<td>13:00-15:00</td>
<td>OS-1-2</td>
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<td>OS –2-3</td>
<td>OS-6-2</td>
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<td>19:00-22:30</td>
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<th>Room 1- Banjaluka</th>
<th>Room 2-Sarajevo I</th>
<th>Room 3 – Sarajevo II</th>
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<tbody>
<tr>
<td>8:45-10:15</td>
<td>Prof. Kouhei Ohnishi &amp; Prof. Asif Šabanović</td>
<td>Round Table: &quot;Mechatronics -- which way it will go? &quot;</td>
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<td>HR-1</td>
<td>BC-1</td>
<td>RO-1</td>
<td>CO-2</td>
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<td>Bilateral Control I</td>
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## Sessions Program

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<td>RO-2</td>
<td>Robotics II</td>
<td>Room 3: Sarajevo II</td>
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Conference Rooms
Plenary Talks

**Uncertainty Principle in Real-Time Communication - Battle of Quickness against Correctness in NBCS-**

Associate Professor Takahiro Yakoh, PhD  
System Design Engineering  
Faculty of Science and Technology  
Keio University  
Yokohama, Japan

**Human Adaptive Mechatronics and Human-System Modeling**

Professor Fumio Harashima, Dr-Eng  
President,  
Tokyo Metropolitan University  
Tokyo, Japan

Dr. Satoshi Suzuki,  
Department of Robotics and Mechatronics,  
School of Science and Technology for Future Life,  
Tokyo Denki University  
Tokyo, Japan

Round Table:  
"Mechatronics -- which way it will go?"

**Organizers:**  
Kouhei Ohnishi  
Keio University, Japan  
Asif Šabanović  
Sabancı University, Turkey
Sessions on Sunday, 25th March
Hour: 15:30 – 17:30

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| OS-3 | Compliant Locomotion Manipulation and Actuation | Sunday, 25th March  
Room 1: Banjaluka  
Hour:15:30-17:30 |
| Session organizers | Yasutaka Fujimoto (Yokohama National University, Japan), Barkan Ugurlu (Toyota Technological Institute, Japan) |
| Chairs | Barkan Ugurlu (Toyota Technological Institute, Japan)  
Matteo Laffranchi (Italian Institute of Technology, Italy) |
| Variable Physical Damping Actuators (VPDAs): Facilitating the Control and Improving the Performance of Compliant Actuation Systems | Matteo Laffranchi (Italian Institute of Technology, Italy), Nikos Tsagarakis (Italian Institute of Technology, Italy), Darwin Caldwell (Italian Institute of Technology, Italy) |
| A Framework for Sensorless Torque Estimation and Control in Wearable Exoskeletons | Barkan Ugurlu (Toyota Technological Institute, Japan), Masayoshi Nishimura (Toyota Technological Institute, Japan), Kazuyuki Hyodo (Toyota Technological Institute, Japan), Michihiro Kawanishi (Toyota Technological Institute, Japan), Tatsuo Narikiyo (Toyota Technological Institute, Japan) |
| Variable Physical Damping Actuators (VPDAs): Facilitating the Control and Improving the Performance of Compliant Actuation Systems | Matteo Laffranchi (Italian Institute of Technology, Italy), Nikos Tsagarakis (Italian Institute of Technology, Italy), Darwin Caldwell (Italian Institute of Technology, Italy) |
| Legged robot locomotion based on free vibration | Fumiya Iida (ETH Zurich, Switzerland), Murat Reis (ETH Zurich, Switzerland), Nandan Maheshwari (ETH Zurich, Switzerland), Keith Gunura (ETH Zurich, Switzerland), Simon Hauser (ETH Zurich, Switzerland) |
| Torque-control based Compliant Actuation of a Quadruped Robot | Michele Focchi (Italian Institute of Technology, Italy), Thiago Boaventura (Italian Institute of Technology, Italy), Claudio Semini (Italian Institute of Technology, Italy), Marco Frigerio (Italian Institute of Technology, Italy), Jonas Buchli (Italian Institute of Technology, Italy), Darwin G. Caldwell (Italian Institute of Technology, Italy) |
| Image-based Visual Feedback Control for Biped Walking Robot | Naoki Oda (Chitose Institute of Science and Technology, Japan), Junichi Yoneda (Chitose Institute of Science and Technology, Japan), Takahiro Abe (Chitose Institute of Science and Technology, Japan) |
| Control of a Biped Robot Driven by Elastomer-based Series Elastic Actuators | Kouki Abe (Yokohama National University, Japan), Takahiro Suga (Yokohama National University, Japan), Yasutaka Fujimoto (Yokohama National University, Japan) |

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| OS-4 | Network-based Control | Sunday, 25th March  
Room 2: Sarajevo I  
Hour:15:30-17:30 |
| Session organizers | Yutaka Uchimura (Shibaura Institute of Technology, Japan), Kenji Natori (Aoyama Gakuin University, Japan) |
| Chairs | Yutaka Uchimura (Shibaura Institute of Technology, Japan), Kenji Natori (Aoyama Gakuin University, Japan) |
| An Arrangement Identification Method for Parallel Multi-Degrees-of-Freedom Teleoperation Systems Based on Levenberg-Marquardt Method | Yoshiyuki Hatta (Yokohama National University, Japan), Tomoyuki Shimono (Yokohama National University, Japan), Naoki Motoi (Yokohama National University, Japan) |
| Controller Design based on Sum-of-Squares for Time-varying Delay Systems | Masanori Nagahara (Shibaura Institute of Technology, Japan), Yusuke Suzuki (Shibaura Institute of Technology, Japan), Yutaka Uchimura (Shibaura Institute of Technology, Japan) |
| PD Controller with LPF based Jitter Buffer for Real-Time Communication | |

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### Sunday, 25th March

**Room: 3: Sarajevo II**

**CO - 1 Control I**

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<tr>
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<tr>
<td>Data Transmission using Motion Detection Based on Sigma-Delta Modulation for Bilateral Control</td>
<td>Daisuke Yashiro (Keio University, Japan), Takahiro Yakoh (Keio University, Japan)</td>
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<tr>
<td>A Design Method of Time-Delay Systems with Communication Disturbance Observer by Using Pade Approximation</td>
<td>Fumiya Mitome (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)</td>
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<td>Network in the Loop Platform for Research and Training in Bilateral Control</td>
<td>Kenji Natori (Aoyama Gakuin University, Japan), Ahmet Kuzu (Tubitak-Bilgem-Bte, Turkey), Seta Bogosyan (University of Alaska Fairbanks, USA), Metin Gokasan (Istanbul Technical University, Turkey)</td>
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**Chairs**

- Karel Jezernik (FERI, University of Maribor, Slovenia)
- Mikulas Huba (STU Bratislava, Slovakia)

### Sessions on Monday, 26th March

**Hour: 10:00 – 12:00**

**OS-1-1 Haptics for Human Support**

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<td>Nonlinear Two-Dimensional Modeling of a McPherson Suspension for Kinematics and Dynamics Simulation</td>
<td>Jorge Hurel (ESPOL, Equador), Anthony Mandow (Universidad de Málaga, Spain), Alfonso García-Cerezo (Universidad de Málaga, Spain)</td>
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<td>Improving the Performance of Higher Order Disturbance Observers: A Position Approach</td>
<td>Emre Sariyildiz (Keio University, Japan), Davide Cattin (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)</td>
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<td>Mechatronic Control System based on a Finite State Machine</td>
<td>Franc Hanži (Doorson d.o.o., Slovenia), Karel Jezernik (FERI, University of Maribor, Slovenia), Slavko Cehner (Doorson d.o.o., Slovenia)</td>
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<tr>
<td>Design of Controller Parameters According to the Transient Indices Using the Dominant Poles Method</td>
<td>Boris Bosnjak (MARUS-ATM, Croatia), Petar Crnosija (Polytechnics of Zagreb, Croatia), Damir Sumina (University of Zagreb, Croatia), Igor Erceg (University of Zagreb, Croatia)</td>
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<tr>
<td>Open flexible P-controller design</td>
<td>Mikulas Huba (STU Bratislava, Slovakia)</td>
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<tr>
<td>Modular disturbance observer based constrained PI-controller design</td>
<td>Mikulas Huba (STU Bratislava, Slovakia)</td>
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**Session organizers**

- Kiyoshi Ohishi (Nagaoka Univ. of Technology, Japan), Seiichiro Katsura (Keio University, Japan), Tomoyuki Shimono (Yokohama National University, Japan)

**Chairs**

- Tomoyuki Shimono (Yokohama National University, Japan)
- Kiyoshi Ohishi (Nagaoka Univ. of Technology, Japan)

**Resonance Ratio Control Based on Coefficient Diagram Method for Force Control of Flexible Robot System**

Chowarit Mitsantisuk (Nagaoka University of Technology, Japan), Manuel Nandayapa (Nagaoka University of Technology, Japan), Kiyoshi Ohishi (Nagaoka University of Technology, Japan), Seiichiro Katsura (Keio University, Japan)
Micro macro bilateral control in the frequency domain
Midori Miyagaki (Keio University, Japan), Kohei Ohnishi (Keio University, Japan)

Wideband Force Control System based on Friction Free and Noise Free Observation
Thao Tran Phuong (Nagaoka University of Technology, Japan), Chawarit Mitsantisuk (Nagaoka University of Technology, Japan), Kiyoshi Ohishi (Nagaoka University of Technology, Japan)

Multilateral Force Feedback Control using Dynamical Modal Transformation
Wataru Yamanouchi (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)

Bilateral Control with Local Force Feedback for Delay-Free Teleoperation
Takumi Ishii (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)

Force-based Variable Compliance Control Method for Bilateral System with Different Degree of Freedom
Naoki Motoi (Yokohama National University, Japan), Tomoyuki Shimono (Yokohama National University, Japan), Ryogo Kubo (Keio University, Japan), Atsuo Kawamura (Yokohama National University, Japan)

OS-2-1  Smart Precise Motion Control - Controller design for precision motion control  Monday, 26th March
Session organizers  Room 2: Sarajevo I
Hour:10:00-12:00

Makoto Iwasaki (Nagoya Inst of Tech, Japan), Hiroshi Fujimoto (The Tokyo Univ, Japan), Roberto Oboe (Univ Padova, Italy)

Trajectory Tracking Control Method Based on Zero-Phase Minimum-Phase Factorization for Nonminimum-Phase Continuous-Time System
Takayuki Shiraishi (University of Tokyo, Japan), Hiroshi Fujimoto (University of Tokyo, Japan)

A Feedback Controller Design Based on Circle Condition for Improvement of Disturbance Suppression
Yoshihiro Maeda (Nagoya Institute of Technology, Japan), Makoto Iwasaki (Nagoya Institute of Technology, Japan)

Optimal Mechanical Parameter Design Using Self Resonance Cancellation Control for Gantry-Type High Precision Stage
Yushi Seki (University of Tokyo, Japan), Hiroshi Fujimoto (University of Tokyo, Japan), Kazuaki Saiki (Nikon Corporation, Japan)

A Coordinate Design of Two-Degrees-Of-Freedom Controller for Fast and Precise Positioning
Takanori Kato (Nagoya Institute of Technology, Japan), Yoshihiro Maeda (Nagoya Institute of Technology, Japan), Makoto Iwasaki (Nagoya Institute of Technology, Japan), Hiromu Hirai (Nagoya Institute of Technology, Japan)

Feedback Controller Design Considering Plant Dynamics of Table Drive System in Microscopic Displacement Region
Kazuaki Ito (Toyota National College of Technology, Japan), Yuichi Katsuki (Nagoya Institute of Technology, Japan), Wataru Maebashi (Nagoya Institute of Technology, Japan), Makoto Iwasaki (Nagoya Institute of Technology, Japan)

Adaptive Robust Precision Motion Control of Linear Motors with High Frequency Flexible Modes
Zheng Chen (Zhejiang University, China), Bin Yao (Zhejiang University, China and Purdue University, USA), Qingfeng Wang (Zhejiang University, China)

OS-5  Advanced Sensing, Estimation and Its Applications  Monday, 26th March
Room 3: Sarajevo II
Hour:10:00-12:00

Naoki Oda (Chitose Institute of Science and Technology, Japan), Toshiyuki Murakami (Keio University, Japan), Kiyoshi Ohishi (Nagaoka University of Technology, Japan), Seiichiro Katsura (Keio University, Japan),
Sessions on Monday, 26th March

Hour: 13:00 – 15:00

OS-1-2  Haptics for Human Support

Monday, 26th March
Room 1: Banjaluka
Hour: 13:00-15:00

Session organizers
Kiyoshi Ohishi(Nagaoka Univ. of Technology, Japan), Seiichiro Katsura (Keio University, Japan), Tomoyuki Shimono (Yokohama National University, Japan)

Chairs
Seiichiro Katsura (Keio University, Japan)
Kiyoshi Ohishi (Nagaoka Univ. of Technology, Japan)

Manipulability Servoing Control in Null Space for Redundant Bilateral Control System with Different Degrees of Freedom
Nobuyuki Togashi (Yokohama National University, Japan), Tomoyuki Shimono (Yokohama National University, Japan), Naoki Motoi (Yokohama National University, Japan)

Towards multimodal Haptics for teleoperation: Design of a Tactile Thermal Display
Simon Gallo (LSRO EPFL, Switzerland), Laura Santos-Carreras (LSRO EPFL, Switzerland), Giulio Rognini (LSRO EPFL, Switzerland), Masayuki Haru (University of Tokyo, Japan), Akio Yamamoto (University of Tokyo, Japan), Toshiro Higuchi (University of Tokyo, Japan), Hannes Bleuler (LSRO EPFL, Switzerland)

The Performance Validation of Disturbance Observer Based on Comparison between Motion Control Frequency and Current Control Frequency
Hiromi Ohkubo (Yokohama National University, Japan), Tomoyuki Shimono (Yokohama National University, Japan), Naoki Motoi (Yokohama National University, Japan)

Identification and Compensation of Disturbance for Real–World Haptics
Takuma Shimoichi (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)

OP Sense – a robotic research platform for telemanipulated and automatic computer assisted surgery
Holger Mönich (KIT, Germany), Heinz Wörrn (KIT, Germany), Daniel Stein (KIT, Germany), Heinz Wörrn (KIT,
### OS-2-2

**Smart Precise Motion Control – Disturbance modeling and compensation in mechatronic systems**

**Session organizers**
- Makoto Iwasaki (Nagoya Inst of Tech, Japan), Hiroshi Fujimoto (The Tokyo Univ, Japan), Roberto Oboe (Univ Padova, Italy)

**Chairs**
- Aleš Hace (University of Maribor, Slovenia)
- Hiroshi Fujimoto (The Tokyo Univ, Japan)

- Develop Actively-controllable Endoscopic Forceps
  Keisuke Sugawara (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

- **Focusing Control System for Suppressing Multi-Harmonic Disturbances in High Speed Optical Disk Systems**
  Tatsuya Nakazaki (Nagaoka University of Technology, Japan), Tokoku Ogata (Nagaoka University of Technology, Japan), Kiyoshi Ohishi (Nagaoka University of Technology, Japan), Toshimas Miyazaki (Nagaoka University of Technology, Japan), Daichi Koide (Japan Broadcasting Corporation, Japan), Yoshimich Takano (Japan Broadcasting Corporation, Japan), Haruki Tokumaru (Japan Broadcasting Corporation, Japan)

- **Friction Compensation Using Time Variant Disturbance Observer Based on the LuGre Model**
  Daiki Hoshino (Tokyo Denki University, Japan), Norihiro Kamamichi (Tokyo Denki University, Japan), Jun Ishikawa (Tokyo Denki University, Japan)

- **High Precision Control of Ball Screw Driven Stage Using Sharp Roll-off Learning Q Filter**
  Tadashi Takemura (University of Tokyo, Japan), Hiroshi Fujimoto (University of Tokyo, Japan)

- **Model-Based Feedforward Compensation for Disturbance Caused by Rotational Motion in 2-Dimensional Shaking Table Systems**
  Kenta Seki (Nagoya Institute of Technology, Japan), Makoto Iwasaki (Nagoya Institute of Technology, Japan)

- **Head Positioning Control System Design Based on Dynamic Characteristic of Rolling Friction in HDDs.**
  Motohiro Kawaku (Nagoya Institute of Technology, Japan), Masato Mizoguchi (Nagoya Institute of Technology, Japan), Makoto Iwasaki (Nagoya Institute of Technology, Japan)

- **A Smoothed GMS Friction Model for Moving Horizon Friction State and Parameter Estimation**

### OS-6-1

**Musculoskeletal Structure based Robotics**

**Session organizers**
- Sehoon Oh (The University of Tokyo, Japan), Toshiaki Tsuji (Saitama University, Japan)

**Chairs**
- Sehoon Oh (The University of Tokyo, Japan)
- Toshiaki Tsuji (Saitama University, Japan)

- **Leg Space Observer on Biarticular Actuated Two-Link Manipulator for Realizing Spring Loaded Inverted Pendulum Model**
  Yasuto Kimura (University of Tokyo, Japan), Sehoon Oh (University of Tokyo, Japan), Yoichi Hori (University of Tokyo, Japan)

- **Force Control of Musculoskeletal Manipulator**
  Ahmad Zaki Shukor (Yokohama National University, Japan), Yasutaka Fujimoto (Yokohama National University, Japan)

- **Development of a Physical Therapy Robot for Rehabilitation Databases**
  Tomonori Yokoo (Saitama University, Japan), Toshiaki Tsuji (Saitama University, Japan), Sho Sakaino (Saitama University, Japan), Shigeru Abe (Saitama University, Japan)
### Analysis of Actuator Redundancy Resolution Methods for Bi-articularly Actuated Robot Arms
Valerio Salvucci (University of Tokyo, Japan), Sehoon Oh (University of Tokyo, Japan), Yoichi Hori (University of Tokyo, Japan)

### Total Harmonic Distortion of Haptic Modal Information for Analysis of Human Fingertip Motion
Tomoyuki Shimono (Yokohama National University, Japan), Yoshiyuki Hatta (Yokohama National University, Japan), Naoki Motoi (Yokohama National University, Japan)

### Force Control of a Spiral Motor and Its Application to Musculoskeletal Biped Robot
Yasutaka Fujimoto (Yokohama National University, Japan), Tsubasa Suenaga (Yokohama National University, Japan), Yuuki Wakayama (Yokohama National University, Japan), Kengo Sawai (Yokohama National University, Japan), Ahmad Zaki (Yokohama National University, Japan)

## Sessions on Monday, 26\(^{th}\) March

**Hour: 15:30 – 17:30**

### ED-1  Electric Drives
**Monday, 26\(^{th}\) March**  
**Room 1: Banjaluka**  
**Hour:15:30-17:50**

**Chairs**  
**Pavol Bauer** (Delft University of Technology, The Netherlands)  
**Vinko Lešić** (University of Zagreb, Croatia)

- **Event-Driven Approach to Control Mechatronic System with FPGA**  
  Robert Horvat (FERI, University of Maribor, Slovenia), Karel Jezernik (FERI, University of Maribor, Slovenia), Milan Čurkovič (FERI, University of Maribor, Slovenia)

- **Fault-tolerant Control of a Wind Turbine with a Squirrel-cage Induction Generator and Stator Inter-turn Faults**  
  Vinko Lešić (University of Zagreb, Croatia), Mario Vašak (University of Zagreb, Croatia), Nedjeljko Perić (University of Zagreb, Croatia), Gojko Joksimović (University of Montenegro, Montenegro), Thomas Wolbank (Vienna University of Technology, Austria)

- **Design and Realization of Hybrid Drive with Supercapacitor and Power Flow control**  
  Marijan Španer (FERI Uni Maribor, Slovenia), Andreja Rojko (FERI Uni Maribor, Slovenia), Karel Jezernik (FERI Uni Maribor, Slovenia)

- **Disturbance estimation of high dynamics sensorless PMSM drive with Unscented Kalman Filter**  
  Dariusz Janiszewski (Poznan University of Technology, Poland)

- **Frequency analysis of mechanical resonance in direct drive**  
  Dominik Luczak (Poznan University of Technology, Poland)

- **Parameter Estimation of Two-Mass Mechanical Loads in Electric Drives**  
  Seppo Saarakkala (Aalto University, Finland), Tuomo Leppinen (ABB Drives, Finland), Marko Hinkkanen (Aalto University, Finland), Jorma Loumi (Aalto University, Finland)

**DriveTrain of Electric Car: Development of Virtual Laboratory for E-learning**
Venugopal Prasanth (Delft University of Technology, The Netherlands), Pavol Bauer (Delft University of Technology, The Netherlands ), Pšenáková Ildikó (Univerzita Konštantína Filozofa, Slovakia)

### OS-2-3  Smart Precise Motion Control - Industrial applications of precision motion control
**Monday, 26\(^{th}\) March**  
**Room 2: Sarajevo I**  
**Hour:15:30-17:30**

**Session organizers**  
Makoto Iwasaki (Nagoya Inst of Tech, Japan), Hiroshi Fujimoto (The Tokyo Univ, Japan), Roberto Oboe (Univ Padova, Italy)

**Chairs**  
Makoto Iwasaki (Nagoya Inst of Tech, Japan)
Dominik Luczak (Poznan University of Technology, Poland)

Anti-sway Sliding-mode with Trolley Disturbance Observer for Overhead Crane system
Jadesada Maneeratanaporn (Keio University, Japan), Toshiyuki Murakami (Keio University, Japan)

High Accurate Modeling of Vehicle Dynamics Considering Three-Dimensional Rotating Motion
Wataru Kubota (Nagoya Institute of Technology, Japan), Motohiro Kawafuki (Nagoya Institute of Technology, Japan), Makoto Iwasaki (Nagoya Institute of Technology, Japan), Hirotaka Tokoro (DENS Corporation, Japan)

Vibration Control of Flexible System With Communication Delay Using Wave Compensator
Eiichi Saito (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)

FPGA Implementation of the Bilateral Control Algorithm for a High Performance Haptic Teleoperation
Marko Franc (Isomat d.o.o., Slovenia), Aleš Hace (University of Maribor, Slovenia)

Force Sensorless Pressure Control Considering Nonlinear Friction Phenomenon for Electric Injection Molding Machine
Ryo Furusawa (Nagaoka University of Technology, Japan), Kiyoshi Ohishi (Nagaoka University of Technology, Japan), Koichi Kageyama (Niigata Machine Techno CO., LTD, Japan), Masaru Takatsu (Niigata Machine Techno CO., LTD, Japan), Shiro Urushihara (Kagawa National College of Technology, Japan)

Study on re-adhesion control by monitoring excessive angular momentum in electric railway tractions
Takafumi Hara (University of Tokyo, Japan), Takafumi Koseki (University of Tokyo, Japan),

OS-6-2 Musculoskeletal Structure based Robotics

Session organizers
Seyoon Oh (The University of Tokyo, Japan), Toshiaki Tsuji (Saitama University, Japan)

Chairs
Toshiaki Tsuji (Saitama University, Japan) 
Seyoon Oh (The University of Tokyo, Japan)

Model-based Compensation of Wire Elongation for Tendon-driven Rotary Actuator
Yuki Saito (Keio University, Japan), Takahiro Nozaki (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

A Method of Joint Torque Control for a Tendon-Driven System
Uichiro Nishio (Keio University, Japan), Takahiro Nozaki (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

Application of Tension Control into Linear Motor-Actuated Cable Differential-Driven Joint
Tomoko Kawase (Keio University, Japan), Keita Shimamoto (Keio University, Japan), Kazuki Tanida (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

Function Separation for 2-DOF Haptic Surgical Forceps Robots driven by Multi Drive Linear Motors
Kazuki Tanida (Keio University, Japan), Takahiro Mizoguchi (Keio University, Japan), Fumiya Mitome (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

A Numerical Simulation Using The Optimal Control Can Estimate Stiffness Profiles of A Monkey Arm during Reaching Movements
Yuki Ueyama (Tokyo Institute of Technology, Japan), Eizo Miyashita (Tokyo Institute of Technology, Japan)

Model-based compensation of hysteresis in the force characteristic of pneumatic muscles
Dominik Schindele (University of Rostock, Germany), Harald Aschemann (University of Rostock, Germany)
## Sessions on Tuesday, 27th March

**Hour:** 10:30-12:30

### HR-1  Humanoid Robots I

**Chairs**
- Kenji Kaneko (AIST, Japan)
- Harald Aschemann (University of Rostock, Germany)

**Tuesday, 27th March**
**Room:** 1: Banjaluka
**Hour:** 10:30-12:30

**Disturbance Observer that estimates External Force acting on Humanoid Robots**
Kenji Kaneko (AIST, Japan), Fumio Kanehiro (AIST, Japan), Mitsuharu Morisawa (AIST, Japan), Eiichi Yoshida (AIST, Japan), Jean-Paul Laumond (LAAS-CNRS, France)

**Falling Risk Evaluation Based on Plantar Contact Points for Biped Robot**
Hisashi Ono (Keio University, Japan), Takahiko Sato (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

**Stable Landing Method for Biped Robot by Using Switching Control**
Kenta Sasahara (Yokohama National University, Japan), Naoki Motoi (Yokohama National University, Japan), Tomoyuki Shimono (Yokohama National University, Japan), Atsuo Kawamura (Yokohama National University, Japan)

**Gyroscoptic Assistance for Human Balance**
Dustin Li (KUSTAR, United Arab Emirates), Heike Vallery (KUSTAR, United Arab Emirates)

**Verification of biped robot using point-contact type foot with springs for walking on rough terrain**
Moyuru Yamada (Toyoohashi University of Technology, Japan), Shigenori Sano (Toyoohashi University of Technology, Japan), Naoki Uchiyama (Toyoohashi University of Technology, Japan)

**Towards integrated walking and jumping motion planning in complex environments: Jumping trajectory generation**
Kirill Van Heerden (Yokohama National University, Japan), Atsuo Kawamura (Yokohama National University, Japan)

### BC-1  Bilateral Control I

**Chairs**
- Toshiyuki Murakami (Keio University, Japan)
- Igor Erceg (University of Zagreb, Croatia)

**Tuesday, 27th March**
**Room:** 2: Sarajevo I
**Hour:** 10:30-12:30

**An Approach to Controller Design of Bilateral Control with Dimensional Scaling**
Takahiro Kosugi (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)

**Position/Force Decoupling for Micro-Macro Bilateral Control based on Modal Space Disturbance Observer**
Takahiro Nozaki (Keio University, Japan), Takahiro Mizoguchi (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

**Separated Master System to Decrease Operational Force of Bilateral Control**
Haruya Sato (Keio University, Japan), Takahiro Mizoguchi (Keio University, Japan), Fumiya Mitome (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

**A Novel Dimensional Scaling Bilateral Control for Realization of Mobile-Hapto**
Shunsuke Yajima (Keio University, Japan), Wataru Yamanouchi (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)

**Transparency Analysis of Motion Canceling Bilateral Control under Sensing Constraints**
Yu Nakajima (Keio University, Japan), Takahiro Nozaki (Keio University, Japan), Takahiro Mizoguchi (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)

**Scaling Bilateral Controls with Impedance Transmission Using Transfer Admittance**
Takahiro Mizoguchi (Keio University, Japan), Takahiro Nozaki (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)
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<td>Hour: 10:30-12:30</td>
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<tr>
<td>Chairs</td>
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<td>Zdenko Kovačić (University of Zagreb, Croatia)</td>
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<td>Zeynep Ekicioğlu Kuzeci (Yildiz Technical University, Turkey)</td>
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<td>Experiment-Based Kinematic Validation of Numeric Modeling and Simulated Control of an Untethered Biomimetic Microrobot in Channel</td>
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<td>Ahmet Fatih Tabak (Sabancı University, Turkey), Serhat Yesilyurt (Sabancı University, Turkey)</td>
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<td>Miniaturized Modular Manipulator Design for High Precision Assembly and Manipulation Tasks</td>
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<td>Emrah Deniz Kunt (Sabancı University, Turkey), Ahmet Teoman Naskali (Sabancı University, Turkey), Asif Sabanovic (Sabancı University, Turkey)</td>
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<td>Derivation of Nonlinear Dynamic Model of Novel Pneumatic Artificial Muscle Manipulator with a Magnetorheological Brake</td>
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<td>Hiroki Tomori (Chuo University, Japan), Yuichiro Midorikawa (Chuo University, Japan), Taro Nakamura (Chuo University Japan)</td>
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<td>Branislav Konjević (HEP Plomin, Croatia), Mario Pučec University of Applied Science, Varaždin, Croatia), Zdenko Kovačić (University of Zagreb, Croatia)</td>
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<td>Workspace analysis of parallel mechanisms through neural networks and genetic algorithms</td>
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<td>Zeynep Ekicioğlu Kuzeci (Yildiz Technical University, Turkey), Huseyin Alp (ISBAKInc, Turkey), Vasfi Emre Omurlu (Yildiz Technical University, Turkey), İbrahim Ozkol (Istanbul Technical University, Turkey)</td>
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<td>Mireia Perez Plius (Sabancı University, Turkey), Metin Yılmaz (Sabancı University, Turkey), Utku Seven (Sabancı University, Turkey), Kemalettin Erbatur (Sabancı University, Turkey)</td>
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<td>Hiroshi Igarashi (Tokyo Denki University, Japan)</td>
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<td>Andreja Rojko (FERI, University of Maribor, Slovenia)</td>
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<td>Position Control of a Seesaw like Platform by Using a Thrust Propeller</td>
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<td>Erol Uyar (Dokuz Eylul University, Turkey), Turgay Akdogan (Dokuz Eylul University, Turkey), Onur Keskin (Dokuz Eylul University, Turkey), Lutfi Mutlu (Dokuz Eylul University, Turkey)</td>
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<td>Interpolated gain-scheduled controllers for an Over-head Crane</td>
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<td>Hiroshi Igarashi (Tokyo Denki University, Japan)</td>
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<td>Acceleration Control of Stacked Piezoelectric Actuator utilizing Disturbance Observer and Reaction Force Observer</td>
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<td>Shinnosuke Yamaoka (Keio University, Japan), Takahiro Nozaki (Keio University, Japan), Daisuke Yashiro (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)</td>
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<td>Merve Acer (Sabancı University, Turkey), Asif Sabanovic (Sabancı University, Turkey)</td>
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<td>Edin Golubovic (Sabancı University, Turkey), Islam S.M. Khalil (Sabancı University, Turkey), Ahmet Ö. Nergiz (Sabancı University, Turkey), Eray A. Baran (Sabancı University, Turkey), Asif Sabanovic (Sabancı University, Turkey)</td>
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# Sessions on Tuesday, 27\textsuperscript{th} March

**HR-2**  
**Humanoid Robots II**

**Chairs**  
Yasutaka Fujimoto (Yokohama National University, Japan)  
Satoshi Suzuki (Tokyo Denki University, Japan)

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<td>Metin Yilmaz (Sabanci University, Turkey), Utku Seven (Sabanci University, Turkey), Kaan Can Fidan (Sabanci University, Turkey), Tunc Akbas (Sabanci University, Turkey), Kemalettin Erbatur (Sabanci University, Turkey)</td>
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<td>Gyroscope Integrated Environmental Mode Compliance Control for Biped Robot</td>
<td>Takahiko Sato (Keio University, Japan), Hisashi Ono (Keio University, Japan), Kouhei Ohnishi (Keio University, Japan)</td>
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<td>A Robotic Walker for Standing Assistance with Realtime Estimation of a Patient’s Load</td>
<td>Daisuke Chugo (Kwansei Gakuin University, Japan), Yusuke Morita (Kwansei Gakuin University, Japan), Yuki Sakaida (RIKEN, Japan), Sho Yokota (Setsunan University, Japan), Kunikatsu Takase (The University of Electro-Communications, Japan)</td>
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<td>High Mobility Control for Wheel-Legged Mobile Robot Based on Resolved Momentum Control</td>
<td>Akihiro Suzumura (Yokohama National University, Japan), Yasutaka Fujimoto (Yokohama National University, Japan)</td>
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<td>Robot motion planning considering the utterance-timing and its experimental evaluation</td>
<td>Satoshi Suzuki (Tokyo Denki University, Japan), Jun Goto (Tokyo Denki University, Japan), Hiroshi Igarashi (Tokyo Denki University, Japan), Harumi Kobayashi (Tokyo Denki University, Japan), Tetsuya Yasuda (Tokyo Denki University, Japan), Fumio Harashima (Tokyo Metropolitan University, Japan)</td>
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**BC-2**  
**Bilateral Control II**

**Chairs**  
Daisuke Yashiro (Keio University, Japan)  
Kemalettin Erbatur (Sabanci University, Turkey)

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<td>Mariko Mizuochi (Hitachi, Ltd, Japan), Kouhei Ohnishi (Keio University, Japan)</td>
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<td>Data Transmission with Multiple-Routes for Wireless Haptic Communication System</td>
<td>Nozomi Suzuki (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)</td>
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<td>Positive Feedback of Reaction Force for Environmental Embedded Haptic System</td>
<td>Hiroyuki Nagai (Keio University, Japan), Seiichiro Katsura (Keio University, Japan)</td>
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<td>Novel Fuzzy - Smith predictor hybrid scheme for periodic disturbance reduction in linear time delay systems</td>
<td>Ahmet Kuzu (Tubitak-Bilgem-Bte, Turkey), Ozgur Songuler (Tubitak-Bilgem-Bte, Turkey)</td>
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<td>Predictive Input Delay Compensation for Motion Control Systems</td>
<td>Eray A. Baran (Sabanci University, Turkey), Asif Sabanovic (Sabanci University, Turkey)</td>
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<td>Low-Noise and Fine-Efficiency Motor Drive for Motion Control</td>
<td>Yuki Yokokura (Nagaoka University of Technology, Japan), Kiyoshi Ohishi (Nagaoka University of Technology, Japan), Seiichiro Katsura (Keio University, Japan)</td>
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Four-wheel Driving-force Distribution Method for Instantaneous or Split Slippery Roads for Electric Vehicle with In-wheel Motors
Kenta Maeda (University of Tokyo, Japan), Hiroshi Fujimoto (University of Tokyo, Japan), Yoichi Hori (University of Tokyo, Japan)

Terrace Climbing of the Alacrane Mobile Robot with Cooperation of its Onboard Arm
Javier Serón (University of Malaga, Spain), Jorge L. Martínez (University of Malaga, Spain), Anthony Mandow (University of Malaga, Spain), Alfonso García-Cerezo (University of Malaga, Spain), Jesus Morales (University of Malaga, Spain), Antonio Reina (University of Malaga, Spain), Jesus Garcia (Universidad Nacional experimental del Táchira, Venezuela)

Modified Histogramic Technique for Mobile Robot Indoor Environment Mapping Based on Uniform Random Distribution
Dinko Osmanković (ETF University of Sarajevo, BiH), Jasmin Velagić (ETF University of Sarajevo, BiH)

Coefficient of Agility and Sampling Frequency issues in Mobile Agents Collision Detection with Dynamic Obstacles in 3D Space
Elmir Babović (FIT Mostar, BiH)

Zero Moment Point Based Pace Reference Generation for Quadruped Robots via Preview Control
Tunc Akbas (Sabanci University, Turkey), Sefik Emre Eskmiz (Sabanci University, Turkey), Selim Ozel (Sabanci University, Turkey), Omer Kemal Adak (Sabanci University, Turkey), Kaan C. Fidan (Sabanci University, Turkey), Kemalettin Erbatur (Sabanci University, Turkey)
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Abstracts

OS-3 Compliant Locomotion Manipulation and Actuation

Variable Physical Damping Actuators (VPDAs): Facilitating the Control and Improving the Performance of Compliant Actuation Systems
Matteo Laffranchi (Italian Institute of Technology, Italy)
Nikos Tsagarakis (Italian Institute of Technology, Italy)
Darwin G. Caldwell (Italian Institute of Technology, Italy)

As recent application domains emerge requiring the employment of robots within unstructured environments, new demands arise requiring more versatile systems which can cope with unpredictable interactions. Recently, compliance has been identified as one of the key features which enables the safe operation of robots interacting with humans and environment. Despite the certain merits gained with the introduction of compliance, this property introduces also some drawbacks as the reduction of the bandwidth achievable in the controlled system and the introduction of oscillatory dynamics which dramatically reduce the stability and accuracy of the system. A solution which can be used to overcome such issues consists in the incorporation of physical damping within the actuator mechatronics. Motivated by the above, this work presents the evolution of such actuators from purely compliant to more complex and performing systems which incorporate variable physical damping as added feature for the development of robust, safe and still well performing robots. The mechatronics of the developed units are analysed. The compact compliant actuator (CompAct™) with variable physical damping is evaluated with experimental trials performed using a prototype unit.

A Framework for Sensorless Torque Estimation and Control in Wearable Exoskeletons
Barkan Ugurlu (Toyota Technological Institute; Japan)
Masayoshi Nishimura (Toyota Technological Institute; Japan)
Kazuyuki Hyodo (Toyota Technological Institute; Japan)
Michihiro Kawanishi (Toyota Technological Institute; Japan)
Tatsuo Narikiyo (Toyota Technological Institute; Japan)

This paper is aimed at describing a framework to implement sensorless torque estimation and control in wearable exoskeletons, for the purpose of handling power augmentation tasks. The proposed method relies on accurately identifying and compensating the joint-level disturbance torques caused by stiction, viscous friction, and gravitational loads. Utilizing off the shelf techniques, the characteristics of these disturbances are primarily identified. Subsequently, additional torque inputs are superimposed to the system via feedforward loops in a way to counteract to these disturbances. Having compensated frictional and gravitational loads acting on the actuation module; we are able to estimate the external torque exerted at each joint by using disturbance observers. In this manner, torque control is enabled without any requirement of built-in torque sensing units. In order to validate the proposed framework, we conducted weight lifting and upholding experiments on able-bodied human subjects with and without wearing the upper extremity of exoskeleton suit. Comparison of EMG and IEMG signals acquired in two cases indicates that the exoskeleton system provides sufficient power augmentation reliably. In conclusion, the proposed method is validated to be efficient and it can be potentially used for rehabilitation, training and power augmentation.

Legged robot locomotion based on free vibration
Fumiya Iida (ETH Zurich, Switzerland)
Murat Reis (ETH Zurich, Switzerland)
Nandan Maheshwari (ETH Zurich, Switzerland)
Keith Gunura (ETH Zurich, Switzerland)
Simon Hauser (ETH Zurich, Switzerland)
Behavioral performances of our legged robots are still far behind those of biological systems. Energy efficiency and locomotion velocity of our robots, for example, are orders of magnitude lower than those of animals, and in order to fill the gap, it requires a radically new approach in the design and control processes. From this perspective, we have been exploring a novel approach to design and control of legged robots which makes use of free vibration of elastic curved beams. We found that this approach not only simplifies the design and manufacturing processes of locomotion robots, but also substantially improves their energy efficiency, which is comparable to those of animals. In this paper, we explain the novelty and principles of this approach through the four representative case studies that we have been exploring, and discuss challenges and perspectives toward future.

**Torque-control based Compliant Actuation of a Quadruped Robot**
Michele Focchi (Italian Institute of Technology, Italy)
Thiago Boaventura (Italian Institute of Technology, Italy)
Claudio Semini (Italian Institute of Technology, Italy)
Marco Frigerio (Italian Institute of Technology, Italy)
Jonas Buchli (Italian Institute of Technology, Italy)
Darwin G. Caldwell (Italian Institute of Technology, Italy)

In the realm of legged locomotion, being compliant to external unperceived impacts is crucial when negotiating unstructured terrain. Impedance control is a useful framework to allow the robot to follow reference trajectories and, at the same time, handle external disturbances. To implement impedance control, high performance torque control in all joints is of great importance. In this paper, the torque control for the electric joints of the HyQ robot is described and its performance assessed. HyQ is a quadruped robot which has hybrid actuation: hydraulic and electric. This work complements our previous work, in which the torque control for the hydraulic joints was addressed. Subsequently, we describe the implementation of an impedance controller for the HyQ leg. Experimental results assess the tracking capability of a desired Cartesian force at the end-effector under the action of external disturbances. Another set of experiments involves the tracking and the shaping of different desired stiffness behaviors (stiffness ellipses) at the foot.

**Image-based Visual Feedback Control for Biped Walking Robot**
Naoki Oda (Chitose Institute of Science and Technology, Japan)
Junichi Yoneda (Chitose Institute of Science and Technology, Japan)
Takahiro Abe (Chitose Institute of Science and Technology, Japan)

This paper presents a image-based visual feedback control for stabilizing the motion of biped walking robot. The appropriate flexibility around ankle joints are given mechanically, and then the zero moment point (ZMP) can be detected by using only vision sensor mounted on the robot in the proposed approach. In the paper, the image-based visual feedback control is designed for getting compliant and stable contact between foot sole and ground, and ZMP stabilizer by using rotational motion around center of gravity is simultaneously implemented for dynamically balanced motion in the image-based visual feedback manner. The control performance of the proposed method is evaluated by several experimental results.

**Control of a Biped Robot Driven by Elastomer-based Series Elastic Actuators**
Kouki Abe (Yokohama National University; Japan)
Takahiro Suga (Yokohama National University; Japan)
Yasutaka Fujimoto (Yokohama National University; Japan)

This paper proposes the novel force control method based on higher-order derivative for high-backdrivable actuation of the robot employing elastomer-based series elastic actuators (SEAs). Control of SEAs is generally difficult because they consist of an underactuated 2-inertia system. Previously, we control it with a position control method. Lately, we employ a torque control method to overcome several problems. The new one enable robot to be controlled more easily, safely and efficiently. To evaluate this method, the experiments of previous position control method, conventional force control method, and proposed force control method are performed.
An Arrangement Identification Method for Parallel Multi-Degrees-of-Freedom Teleoperation Systems Based on Levenberg-Marquardt Method
Yoshiyuki Hatta (Yokohama National University; Japan)
Tomoyuki Shimono (Yokohama National University; Japan)
Naoki Motoi (Yokohama National University; Japan)

In recent years, haptic communication with teleoperation systems has been actively researched. One of the effective methods for haptic communication is bilateral motion control based on acceleration control. If the acceleration-based bilateral control is applied to a parallel multi-degrees-of-freedom (MDOF) system, complicated haptic human motion can be realized in the remote site. But it is difficult to understand whole motion of the system based only on information of each actuator. One of the effective methods for the motion recognition is modal decomposition based on Discrete Fourier series expansion (DFS). This modal decomposition is effective for the analysis of motion of parallel MDOF systems. However, in order to apply the modal decomposition, it is necessary that an arrangement of the parallel MDOF system is known. This paper proposes an arrangement identification method for parallel MDOF teleoperation systems based on Levenberg-Marquardt (LM) method. The method can estimate the arrangement, even if there is no visual information. Finally, the validity of the proposed method is confirmed by the experimental results.

Controller Design based on Sum-of-Squares for Time-varying Delay Systems
Masanori Nagahara (Shibaura Institute of Technology, Japan)
Yusuke Suzuki (Shibaura Institute of Technology, Japan)
Yutaka Uchimura (Shibaura Institute of Technology, Japan)

This paper proposes a controller design based on sum-of-squares (SOS) method for time-varying delay systems. The SOS condition for controller design and the proof based on the Lyapunov-Krasovskii stability theorem are shown. The performance of the controller is fine-tuned taking into account input-output property. The controller is solved by decomposing a SOS condition, which is given by convex form. Experimental results on a real plant are also described to evaluate the performance of the proposed method.

PD Controller with LPF based Jitter Buffer for Real-Time Communication
Daisuke Yashiro (Keio University, Japan)
Takahiro Yakoh (Keio University, Japan)

This paper proposes a jitter buffer for IP-based network which regulates packet-receiving interval. The proposed method utilizes a PD controller to adjust queue length of the jitter buffer to avoid overrun and underrun. In addition, the derivative value of packet-receiving interval is converged to zero by a low-pass filter. Proposed jitter buffer improves control performance of feedback control systems including time-varying delay elements. Validity of the proposed method is confirmed by experiments of position control through a network emulator.

Data Transmission using Motion Detection Based on Sigma-Delta Modulation for Bilateral Control
Fumiya Mitome (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

The \(\Sigma-\Delta\) estimation is a simple non linear method of background estimation used in the field of image processing. We propose the method of data transmission using the \(\Sigma-\Delta\) modulation under narrow bandwidth, which degrades the performance due to time-iscretization. In this paper, the \(\Sigma-\Delta\) estimation is used as a method of motion detection of motors, and high priority is added to detected data. Hierarchical Token Bucket, which controls traffic in a link, discriminates motion data, and handles the packet with high priority preferentially. The motion detection algorithm based on traffic control is implemented into two degree-of-freedom robots to verify the validity of the proposed method. Effectiveness of the proposed method is verified through experiments.
A Design Method of Time-Delay Systems with Communication Disturbance Observer by Using Pade Approximation
Kenji Natori (Aoyama Gakuin University, Japan)

This paper studies a design method of time-delay systems with communication disturbance observer (CDOB). A time-delay compensation method based on network disturbance (ND) concept and CDOB has been proposed and applied to various control systems. It compensates time-delay effect without using time-delay model and the effectiveness is identical with that of Smith predictor. Furthermore, it works even when time-delay value is unknown, since it does not need time-delay model. In past works, some design methods of the time-delay systems with CDOB have been studied basically by using Nyquist diagram. However, detailed design methods of the transient characteristics have not been researched well due to the characteristics of Nyquist diagrams. In other words, we have not addressed design method based on detailed pole placements studies in order to arbitrarily design the transient characteristics. In this paper, we study a design method of the time-delay systems with CDOB based on pole placements by using Pade approximation. The detailed design of the transient characteristics is accomplished by the analytical results. The adequacy of the presented design method is validated by simulation studies.

Network in the Loop Platform for Research and Training in Bilateral Control
Ahmet Kuzu (Tubitak-Bilgem-Bte, Turkey)
Seta Bogosyan (University of Alaska Fairbanks, USA)
Metin Gokasan (Istanbul Technical University, Turkey)

This paper introduces a test platform for research and education in bilateral control system. The so-called network-in-the-loop (NIL) platform aims to provide a realistic test environment for such systems, particularly in terms of testing the developed control algorithms under actual network delay. The platform is designed with two xPc targets which communicate with each other over the Internet. A novel contribution of the platform is that it allows for the realistic and yet, low-cost simulations of bilateral control topologies under real word Internet delay, without the need for the actual manipulators or related hardware. A small case study is also presented to test the performance of the platform.

CO-1 Control I

Nonlinear Two-Dimensional Modeling of a McPherson Suspension for Kinematics and Dynamics Simulation
Jorge Hurel (ESPOL, Ecuador)
Anthony Mando (Universidad de Málaga, Spain)
Alfonso Garcia-Cerezo (Universidad de Málaga, Spain)

This paper proposes a systematic and comprehensive development of a nonlinear two-dimensional mathematical quarter-car model of the McPherson suspension. The model considers vertical motion of the sprung mass (chassis), and rotation and translation for the unsprung mass (wheel assembly). Furthermore, this model includes the wheel mass and its inertia moment about the longitudinal axis. Thus, the proposed improves the conventional quarter-car model by incorporating both the suspension geometry and the tyre lateral stiffness, which allows analyzing variations in kinematic parameters, such as camber angle and track width. Besides, the paper offers an implementation of the model using Matlab-Simulink. The dynamics and kinematics provided by the model have been validated against a realistic two-dimensional model developed with the Adams View program.

Improving the Performance of Higher Order Disturbance Observers: A Position Approach
Emre Sariyildiz (Keio University, Japan)
Davide Cattin (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)
The disturbance observer (DOB) is a tool for the robust motion control and it is used to compensate the disturbances. In the design of the DOB, it is assumed that, the system disturbance is observed and compensated by the DOB in the range of its bandwidth. However, the whole bandwidth cannot be compensated by the DOB due to the dynamical characteristics of the disturbance observer’s low pass filter (LPF). Higher Order Disturbance Observer (HODOB) is one of the fundamental tools to increase the performance of the DOB, even though it has some disadvantages. However, the performance analysis of HODOB has not been clearly reported yet. In this paper, analysis and design methods of the HODOB are presented by using a more general disturbance model. This general model gives more freedoms to design HODOB. Also the superiors of the position measurement based HODOB design are shown. Simulation and experimental results are given to show the validity of the proposed methods.

**Mechatronic Control System based on a Finite State Machine**

Franc Hanžič (Doorson d.o.o., Slovenia)
Karel Jezernik (FERI, University of Maribor, Slovenia)
Slavko Cehner (Doorson d.o.o., Slovenia)

This article describes automatic sliding door control software design based on FSM. The control software is developed in a Matlab/Simulink – Stateflow programming language for door control improvement researching. A smoother door movement, adaptive control, and door hardware capacity detection (motor power) are included in the door improvements. Concurrency, increasingly demanding customers, technology improvements, and electrical energy usage reduction are reasons for the needed improvement. An adaptive motion generator software design based on FSM is a main part of this article.

**Design of Controller Parameters According to the Transient Indices Using the Dominant Poles Method**

Boris Bosnjak (MARUS-ATM, Croatia)
Petar Crnošija (Polytechnics of Zagreb, Croatia)
Damir Sumina (University of Zagreb, Croatia)
Igor Erceg (University of Zagreb, Croatia)

In literature, the dominant poles method is applied for the determination of controller parameters for the processes with the gain coefficient and dominant time constant equal to unity, and with the given values of relative damping coefficient and undamped (natural) system frequency. In this paper the method for determining the PI controller parameters according to the given peak overshoot and time of peak response by using the dominant poles method is described. The method is applied for PI controller parameters determination of DC motor drive for different values of peak overshoot and time of peak response. The procedure for obtaining a desired overshoot response and the most favourable controller parameters is elaborated. System’s responses to the step change of the reference signal and obtained by computer simulation are given in the paper for different values of controller parameters.

**Open flexible P-controller design**

Mikulas Huba (STU Bratislava, Slovakia)

The paper represents first part of two contributions dealing with simplified modular design of constrained P and disturbance observer (DO) based PI control with different filtering properties illustrated by example of speed servo control. This first part is devoted to analysis of the core structure of the P controller tuned for different types of nonmodelled or filter dynamics. Openness of the approach means that for approximating additional dynamics of the P-controller structure different filters may be used without necessity to repeat in the nominal case analysis of the optimal and critical tuning. By simpler means, flexible approach enabling to fit requirements of particular loop and simultaneously offering reasonably better performance than the traditional controller design based on Luenberger disturbance observer for reconstruction of the velocity signal is proposed. Achieved performance is evaluated by newly introduced measures for deviations from monotonic and one-pulse shapes of transients typical for control of plants with dominant 1st order dynamics.
Modular disturbance observer based constrained PI-controller design
Mikulas Huba (STU Bratislava, Slovakia)

The paper deals with modular design of constrained disturbance observer (DO) based PI control with different filtering properties. After treating possible effects of control constraints completing deeper analysis of the core structure of the P controller with different types of additional dynamics approximations [1], it will be expanded by considering structures of constrained PI1 controllers, in which the integral action is introduced as the DO based load (input disturbance) reconstruction and compensation using inversion of the plant dynamics. In the nominal case, for suppressing measurement and quantization noise different DO filters may be used without necessity to repeat for the new structure analysis of the optimal and critical P controller tuning. So, by simple means, open and flexible approach offering reasonably better performance than the traditional PI control is achieved. Thereby, the loop performance is evaluated by measuring deviations from strictly monotonic (MO) and one-pulse (1P) transients typical for plants with dominant first order dynamics [1], as illustrated by example of speed servo control using incremental encoder.

OS-1-1 Haptics for Human Support

Resonance Ratio Control Based on Coefficient Diagram Method for Force Control of Flexible Robot System
Chowarit Mitsantisuk (Nagaoka University of Technology, Japan)
Manuel Nandayapa (Nagaoka University of Technology, Japan)
Kiyoshi Ohishi (Nagaoka University of Technology, Japan)
Seiichiro Katsura (Keio University, Japan)

In the robot systems and intelligent machines, the gear-box or mechanisms are connected with the motor to transmit the actuator torque to a distant joint. Generally, its elasticity causes resonance frequency in the system. By using the conventional PID controller, this method cannot perform well in this situation. Much research has proceeded with the aim of reducing vibration. A new effective control method, the resonance ratio control, has been introduced as a new way to guarantee the robustness and suppress the oscillation during task executions for a position and force control. In this paper, two techniques are proposed for improving the performance of resonance ratio control: 1) A new multi encoder based disturbance observer (MEDOB) is shown to estimate the disturbance force on the load side. The proposed observer is not necessary to identify the nominal spring coefficient. 2) A coefficient diagram method (CDM) has been applied to calculate a new gain controller. A new resonance ratio gain has been presented as 2. The effectiveness of the method is verified by simulation and experimental results.

Micro macro bilateral control in the frequency domain
Midori Miyagaki (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

Recently, a transmission of haptic senses is taken attention. “Bilateral control” is a technique of transmitting haptic senses of a remote environment with master-slave system. However, the original haptic senses of soft environments are so small that it is difficult to recognize. In that case, the recognition of the haptic senses becomes easier by scaling force information in the frequency domain. In this paper, the bilateral control is proposed which can scale only force with arbitrary frequency domain. In a conventional method, force information with the arbitrary frequency domain is scaled with online Fourier transformation. Thus, there is a delay in the conventional method. In the proposed method, only slave force information is scaled by using the complex number as a scaling rate. The complex number scaling rate contains a function of a filter. As a result, the proposed method had no delay and could scale force with the arbitrary frequency domain. Stability analyses with root locus showed that the proposed method were stable. Frequency characteristics were also analyzed. Validity of the analyzed frequency characteristics was confirmed through experiments. In addition, the validity
of the proposed method was shown through penetrating experiments by enhancing force at the instant of penetrating through a film.

**Wideband Force Control System based on Friction Free and Noise Free Observation**
Thao Tran Phuong (Nagaoka University of Technology, Japan)
Chowarit Mitsantisuk (Nagaoka University of Technology, Japan)
Kiyoshi Ohishi (Nagaoka University of Technology, Japan)

In this paper, a new force sensing technique is proposed to achieve a friction free and wideband force control of a ball screw system. A periodic signal is inserted into the control system for friction reduction. A combination of a high-order disturbance observer and a Kalman-filter is constructed to perform the force sensing operation. The high-order disturbance observer is designed to obtain force estimation with the cancellation of oscillatory disturbance caused by additional periodic signal. The force sensing bandwidth is improved owing to the effective noise suppression in the estimated force by Kalman-filter. Additionally, all of the control algorithms are implemented in a Field Programmable Gate Array (FPGA) with a fast sampling rate that also enables the ability to widen the bandwidth of the force control system. The effectiveness of the proposed method is verified by experimental results.

**Multilateral Force Feedback Control using Dynamical Modal Transformation**
Wataru Yamanouchi (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

Recent advances in control technology have contributed to the development of robot systems for communication. Robot systems recognize their environment on the basis of audio-visual information. Recognition methods based on audio-visual feedback have been developed by many researchers. Apart from auditory and visual information, haptic information has recently attracted attention as the third type of multimedia information. The sense of touch is useful for remote manipulation. Feedback of haptic information is realized by bilateral control. Most systems are constructed using a master-slave system in which the master-slave systems have the same mechanical structure. However, we proposed force feedback systems with different mechanical structures. Previous research proposed novel transformation matrix for different mechanical structures including Laplace operator. In this research, effect of integro-differential scaling for proposed modal transformation is verified to experiment.

**Bilateral Control with Local Force Feedback for Delay-Free Teleoperation**
Takumi Ishii (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

Bilateral teleoperation system through network is negatively affected to stability by communication delay. In this paper, bilateral teleoperation system is researched toward a delay free bilateral teleoperation. By using 2ch bilateral control which is transmitting and controlling only positions, the stability of bilateral teleoperation system is enhanced. However, the bilateral teleoperation controlling only position increases force needed to operate master system. So, the operationality comes down, and teleoperation becomes difficult. Therefore, in order to enhance the operationality, local force feedback loop is added, and external force is controlled to 0. So, the proposed method enhances the stability while keeping good operationality. As a result, it turns out that the bilateral control system can enhance the performance of communication delay by reducing connectability of master and slave.

**Force-based Variable Compliance Control Method for Bilateral System with Different Degree of Freedom**
Naoki Motoi (Yokohama National University; Japan)
Tomoyuki Shimono (Yokohama National University; Japan)
Ryogo Kubo (Keio University, Japan)
Atsuo Kawamura (Yokohama National University; Japan)
This paper proposes the force-based variable compliance control method for the bilateral system with different degree of freedom (DOF). In the conventional researches, there are several bilateral control methods with different DOF. In this research, it is assumed that DOF of a master robot is higher than one of a slave robot. In order to control the bilateral system with this assumption, “bilateral control for task realization” and “automatic control for adaptation to contact environment” are necessary. This paper focuses on automatic control of slave system for adaptation to contact environment. Considering the automatic control of slave system, the control method should be switched according to the contact condition between the slave system and the object. Therefore, the force-based variable compliance control method is proposed. The validity of the proposed method is confirmed by the experimental results.

OS-2-1 Smart Precise Motion Control – Controller design for precision motion control

Trajectory Tracking Control Method Based on Zero-Phase Minimum-Phase Factorization for Nonminimum-Phase Continuous-Time System
Takayuki Shiraishi (University of Tokyo, Japan)
Hiroshi Fujimoto (University of Tokyo, Japan)
The purpose of this paper is development of high-precision trajectory tracking control for nonminimum-phase continuous-time systems with unstable zeros. This paper proposes a two degree of freedom control system design method that is based on a novel factorization method for nonminimum-phase continuous-time systems. First, nonminimum-phase continuous-time systems is factorized to minimum-phase system and zero-phase system in continuous-time domain. The feedforward controller is constructed from inverse system of each factorized system. The inverse system of the minimum-phase system is designed by multi-rate perfect model following control theory, and the inverse system of zero-phase system is designed by zero-phase FIR filter. Finally, This paper shows the effectiveness of proposed method by simulation and experimental results.

A Feedback Controller Design Based on Circle Condition for Improvement of Disturbance Suppression
Yoshihiro Maeda (Nagoya Institute of Technology, Japan)
Makoto Iwasaki (Nagoya Institute of Technology, Japan)
This paper presents a novel feedback (FB) controller design methodology for the fast and precise positioning of mechatronic systems. Improvement of the disturbance suppression performance is a general and important index in the FB controller design to realize the precision performance. However, since the stability of the FB system generally limits the disturbance suppression capability, improvement of both the disturbance suppression and the stability should be difficult to achieve. In this study, therefore, a FB controller which considers the stability margins (i.e. gain and phase margins) is designed on the basis of a circle condition on the nyquist diagram, to achieve the required disturbance suppression with the desired stability margins. Effectiveness of the proposed approach has been verified by numerical simulations and experiments using a prototype of linear motor-driven table systems.

Optimal Mechanical Parameter Design Using Self Resonance Cancellation Control for Gantry-Type High Precision Stage
Yushi Seki (University of Tokyo, Japan)
Hiroshi Fujimoto (University of Tokyo, Japan)
Kazuaki Saiki (Nikon Corporation, Japan)
In general, Gantry-type precision stages have the low resonance modes because the structure of the stages are large and complex. These resonance modes cause a pitching during the translation driving. In this paper, an optimal mechanical design method is analyzed and explored via a two-inertia model. First resonance is suppressed by Self Resonance Cancellation (SRC) and secondary resonance is reduced by adjusting the mechanical parameter of the stage. Simulations and experiments with an experimental precision stage are
performed to show the advantages of the proposed optimization method. Moreover, the design method by considering the tolerance is also discussed and verified via experiments

**A Coordinate Design of Two-Degrees-Of-Freedom Controller for Fast and Precise Positioning**
Takanori Kato (Nagoya Institute of Technology, Japan)
Yoshihiro Maeda (Nagoya Institute of Technology, Japan)
Makoto Iwasaki (Nagoya Institute of Technology, Japan)
Hiromu Hirai (Nagoya Institute of Technology, Japan)

This paper presents a novel robust 2-degrees-of-freedom (2-DOF) positioning controller design methodology against frequency perturbations in mechanical vibration modes. The authors have already proposed an LMI (linear matrix inequality)-based feedforward (FF) compensator design to provide robust properties in positioning against the perturbations, where a feedback (FB) controller has been independently designed to ensure the robust stability on the basis of the 2-DOF controller design framework. A problem, however, still remains that the undesired response in the FB system due to the perturbations deteriorates the ideal response by the FF compensation. The proposed controller design, therefore, considers the FB system in the FF compensator design to solve the problem. In addition, the FB controller is redesigned to improve the positioning performance as a coordinate design between the FB and the FF controllers. The effectiveness of the proposed approach has been verified by numerical simulations and experiments using a prototype of galvano scanners.

**Feedback Controller Design Considering Plant Dynamics of Table Drive System in Microscopic Displacement Region**
Kazuaki Ito (Toyota National College of Technology, Japan)
Yuichi Katsuki (Nagoya Institute of Technology, Japan)
Wataru Maebashi (Nagoya Institute of Technology, Japan)
Makoto Iwasaki (Nagoya Institute of Technology, Japan)

This paper presents a feedback controller design approach of a ball screw-driven table system in the microscopic displacement region. Since friction behaves as a nonlinear spring in the microscopic displacement region, while it behaves as Coulomb and a viscous friction in the coarse displacement region, frequency characteristics of the system vary depending on the above regions. In this paper, the stability condition in the microscopic displacement region is clarified, and the appropriate parameters of the feedback controller are obtained. The effectiveness of the proposed control approach has been verified using a prototype of a ball screw-driven table system.

**Adaptive Robust Precision Motion Control of Linear Motors with High Frequency Flexible Modes**
Zheng Chen (Zhejiang University, China)
Bin Yao (Zhejiang University, China and Purdue University, USA)
Qingfeng Wang (Zhejiang University, China)

This paper studies precision motion control of linear motors in the presence of parameter variations, disturbances and various significant nonlinearity effects. An adaptive robust control (ARC) algorithm with integrated compensation of major nonlinearities ranging from Coulomb friction and cogging force to the nonlinear electromagnetic field effect is developed. High frequency structural flexible modes and dynamics in linear motors, which are neglected in the previous researches, are explicitly identified experimentally and their effects are carefully examined. With the knowledge of those high frequency dynamics, theoretical analysis is subsequently conducted to generate a set of practically useful guidelines on the tuning of controller gains in maximizing the achievable performance in practice. Comparative experiments of the propose ARC control law with different controller gains are carried out to illustrate the usefulness of the generated guidelines. In addition, to further push the achievable control performance, explicit compensation of the known high-frequency flexible modes and dynamics using pole/zero cancelation is also investigated, and its effectiveness is evaluated through comparative experimental results as well.
OS-5 Advanced Sensing, Estimation and Its Applications

Improving Bilateral Control Feedback by Using Novel Velocity and Acceleration Estimation Methods in FPGA
Manuel Nandayapa (Nagaoka University of Technology, Japan)
Chowarit Mitsantisuk (Nagaoka University of Technology, Japan)
Kiyoshi Ohishi (Nagaoka University of Technology, Japan)
The bilateral control that is used in medical or industrial applications needs to offer rapid processing and precision. The Field Programmable Gate Array (FPGA) helps in this regard. The algorithms of velocity and acceleration estimation require a short processing time in implementation than do conventional estimation methods. Bilateral control is implemented in common and differential modes for force servoing and position regulator, respectively. Position, velocity and acceleration (PVA) feedback in the differential mode enhance position tracking in the bilateral control. The bilateral robot system is implemented using ball screw mechanisms.

A Design of the Preference Acquisition Detection System using the EEG
Yuna Negishi (Keio University, Japan)
Yasue Mitsukura (Keio University, Japan)
Hironobu Fukai (Ritsumeikan University, Japan)
Yohei Tomita (ESPCI, France)
Estimation of emotional states has been multi-disciplinary research interests. Among them, although there are many ways of the estimation such as subjective evaluations and behavioral taxonomy, direct evaluation from the human brain is more reliable. Especially, electroencephalographic (EEG) signal analysis is widely used because of its simplicity and convenience. In our research, emotional states are investigated with a simple electroencephalography which has only one electrode. This device is lighter and cheaper than existing devices, however, its feasibility has yet been proven.

Walker’s Motion Model Based Control of Two-Wheel Mobile Manipulator
Mayuko Watanabe (Keio University, Japan)
Toshiyuki Murakami (Keio University, Japan)
Human-friendly robots are garnering attention for the next generation for assist human motion in the field of nursing care, home care, soothing care and so on. However, the cooperative motion between human and robots using mobile robots has not yet been researched very much. To address this problem, this paper presents the application of motion control method for safe navigation based on human’s behavior model using two-wheel mobile manipulator, because it has better mobility and it can pinwheel. In this study, human’s behavior model is modeled as 4-link walking model and the force from human model is used to control the mobile manipulator. To verify the validity of proposed method, simulations of human-robot cooperative motion were carried out. By simulation results, the effect of proposed approach is made definite and safe walking support is realized.

Optical flow generation in color images with using Color Derivative Vector
Masaaki Shibata (Seikei University; Japan)
Naoya Ushigome (Seikei University; Japan)
Masahide Ito (Seikei University; Japan)
The paper proposes a novel method for estimating the optical flows from the sequentially captured images with using their own color information. The gradient method is well known as one of the conventional methods to estimate the flows, and then the spatial and temporal derivative of the images are used in the method. Since the color images have richer information than the monochrome ones, they should contribute for estimating the more precise optical flows. In our approach, the color derivative vector (CDV) is introduced to bring out the information in the color images for the optical flow estimation. The CDV is derived from the derivatives of color
images, and the optimal CDV provides the concrete weighting values of the RGB data. The optimal CDV is obtained with using the eigenvalues and the eigenvectors of the matrix consisting of the spatial and temporal color derivatives.

**Visual Posture Estimation and Control for Redundant Manipulator**
Naoki Oda (Chitose Institute of Science and Technology, Japan)
Noriaki Fujinaga (Chitose Institute of Science and Technology, Japan)
The paper presents an approach to the posture control of redundant manipulator by using visual feedback. The redundant degrees-of-freedom enables several dexterous motion according to environmental information such as obstacle avoidance. In the paper, the hybrid motion controller including both the posture controller by visual feedback and end-effector motion controller by using encoder signal is proposed. In the posture controller, the manipulator pose is estimated by particle filter from visual information. That means the posture control is completely realized only by vision sensor signal in our approach. The control model for obstacle avoidance in null space is also proposed by using the optical flow field which is detected by vision. The validity is evaluated by several experimental results.

**Recognition and Classification of Human Motion Based on Hidden Markov Model for Motion Database**
Yoshihiro Ohnishi (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)
In some countries, many problems according to aging are pointed out. Decrease of worker’s physical ability is one of them. The old workers have high techniques, but physical ability is lower than that of young workers. And it becomes difficult to keep high quality. Hence it is thought that a power assist by robot is needed. The method that increases human motion simply is mainstream conventional power assist method. However, to assist accurately it is thought that robot has to recognize human motion and has to assist fitly. Hence, the system that save and reproduce human motion “motion database” is necessary. Here, to assist accurately, the motion which includes force information is saved to database. In this research, the trajectory information and the force information of human motion is extracted by using bilateral control and it is modeled. To reproduce appropriate motion from database, a search system is needed. For adapting power assist, the search system should be real-time and be able to search at all times. Therefore, in this research, a real-time motion searching method is proposed. The searching method is based on hidden Markov model because human motion has Markov property. Proposed method can search human motion on real-time while human does motion. The viability of proposed method is confirmed by motion search experiment.

**OS-1-2 Haptics for Human Support**

**Manipulability Servoing Control in Null Space for Redundant Bilateral Control System with Different Degrees of Freedom**
Nobuyuki Togashi (Yokohama National University; Japan)
Tomoyuki Shimono (Yokohama National University; Japan)
Naoki Motoi (Yokohama National University; Japan)
This paper proposes a manipulability servoing control method in null space for redundant bilateral control system with different degrees of freedom (DOF). In the redundant bilateral system, the error of manipulability in work space is aroused because of a different DOF between master and slave systems. As a result, it is difficult to achieve the precise motion control. In order to solve this problem, a bilateral control method based on null space with the manipulability measure is proposed. This paper verifies the effectiveness of the proposed method by simulation and experimental results.
**Towards multimodal Haptics for teleoperation: Design of a Tactile Thermal Display**
Simon Gallo (LSRO EPFL, Switzerland)  
Laura Santos-Carreras (LSRO EPFL, Switzerland)  
Giulio Rognini (LSRO EPFL, Switzerland)  
Masayuki Hara (University of Tokyo, Japan)  
Akio Yamamoto (University of Tokyo, Japan)  
Toshiro Higuchi (University of Tokyo, Japan)  
Hannes Bleuler (LSRO EPFL, Switzerland)

Surgical robotics is among the most challenging applications of motion control. Present and future systems are essentially master-slave systems. Our work focuses on force feedback and haptic interfaces. In this context, we study multimodal haptic interfaces, i.e. the fusion of force-feedback, with other tactile information such as temperature or pressure. First results support the proposition that such multimodal haptic devices can help improve surgeon's dexterity and motion control. In order to strengthen this point, we investigate the psychophysics of thermal perception. This paper presents a device for temperature feedback that can be integrated in a multimodal haptic console. A finger sized tactile temperature display able to generate temperature gradients under the fingertip is presented along with first measurement results.

**The Performance Validation of Disturbance Observer Based on Comparison between Motion Control Frequency and Current Control Frequency**
Hiromi Ohkubo (Yokohama National University; Japan)  
Tomoyuki Shimono (Yokohama National University; Japan)  
Naoki Motoi (Yokohama National University; Japan)

Recently, a lot of robots and industrial machines with disturbance observer (DOB) have been put to practical use all over the world. By using DOB, acceleration control is achieved. As a result, DOB is contributed to robust position and force control. In other front, DOB is utilized as the reaction force observer (RFOB) for estimation of the external force. As a result, DOB is a key technology for motion control. Therefore, it is necessary to improve the performance of DOB to realize high advanced motion control system. The performance of DOB depends on motion control frequency, current control frequency of motor driver and the resolution of encoder. This paper focuses on motion control frequency and current control frequency. The purpose of this paper is realization of high-performance DOB based on fast motion control frequency and fast current control frequency.

**Identification and Compensation of Disturbance for Real—World Haptics**
Takuma Shimoichi (Keio University, Japan)  
Seiichiro Katsura (Keio University, Japan)

Recently, the real-world haptics which deals with real-world tactile sense has been actively researched. In the real-world haptics, tactile information is dealt with by an actuator as a disturbance force. Therefore, a disturbance in the actuator has to be minimized for clearer tactile information. If the disturbance is known in advance, the pure tactile information is able to be observed by compensation of the disturbance. So this paper proposes a method of determining modeled disturbance-parameter-values of an actuator. The proposed method is achieved by an optimization between bilateral control and disturbance model. The performance of bilateral control is increased by compensation of the disturbance using the proposal. The effectiveness of the proposed method is shown by experiments.

**OP Sense - a robotic research platform for telemanipulated and automatic computer assisted surgery**
Holger Mönich (KIT, Germany)  
Heinz Wörn (KIT, Germany)  
Daniel Stein (KIT, Germany)

OP Sense is a research platform developed for applications in robotic assisted surgery. The system can be used for automatic positioning tasks, like CO2 laser cutting or conventional bone cutting techniques or highly accurate positioning, like needle placement in biopsie. Due to the flexibility of the used lightweight robots the
Development of Actively-controllable Endoscopic Forceps
Keisuke Sugawara (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

An endoscopic forceps is one of the efficient medical devices in minimally invasive surgery. However, the endoscopic forceps has two big problems. First is the endoscopic forceps has friction, and it nonlinearly changes depend on shape of the endoscopic forceps. The friction cause deterioration of operation performance. Second is the endoscopic forceps has only 1-DOF for grasping motion. Therefore, in this paper, Actively-controllable endoscopic forceps is developed. This endoscopic forceps has 2-DOF which are for grasping motion and bending motion. By bending motion, the endoscopic forceps can keep or change shape by itself. In addition, friction associated with changing shape of the endoscopic forceps is modeled by least-square method. Finally, the friction models are applied to bilateral control system. Friction of the endoscopic forceps is compensated, and improvement of operational performance is achieved.

OS-2-2 Smart Precise Motion Control – Disturbance modeling and compensation in mechatronic systems

Focusing Control System for Suppressing Multi-Harmonic Disturbances in High Speed Optical Disk Systems
Tatsuya Nakazaki (Nagaoka University of Technology, Japan)
Tokoku Ogata (Nagaoka University of Technology, Japan)
Kiyoshi Ohashi (Nagaoka University of Technology, Japan)
Toshimasa Miyazaki (Nagaoka University of Technology, Japan)
Daichi Koide (Japan Broadcasting Corporation, Japan)
Yoshimichi Takano (Japan Broadcasting Corporation, Japan)
Haruki Tokumaru (Japan Broadcasting Corporation, Japan)

Recently, the size of digital content has continued to increase; therefore digital storage media have been required to increase capacity by narrowing the track pitch and the gap length between the optical head and the disk. On the other hand, a new optical disk has achieved a rotation speed of over 15,000 rpm. To meet these demands, several control systems for optical disks are proposed to achieve high-precision tracking control. In this paper, a high-precision focusing control system is proposed. The proposed control system consists of a feedback controller and a feedforward controller. The feedback controller design is based on a high-gain servo controller (HGSC). The feedforward controller design is based on a zero phase error tracking (ZPET) controller and an additional loop for suppressing multi-harmonic disturbances. The experimental results show the proposed control system has a fine focusing performance against fundamental periodic disturbances and high-order disturbances.

Friction Compensation Using Time Variant Disturbance Observer Based on the LuGre Model
Daiki Hoshino (Tokyo Denki University, Japan)
Norihiro Kamamichi (Tokyo Denki University, Japan)
Jun Ishikawa (Tokyo Denki University, Japan)

This paper reports experimental evaluation results of a time variant disturbance observer based on the LuGre friction model for friction compensation. The observer is designed from state space expressions of a controlled plant with the LuGre model that is locally-linearized every sampling period. Thus, observer gains derived from the linearized model become time variant ones as a function of velocity. Parameters of the LuGre model were
experimentally identified for a linear stage driven by a ball screw with an AC motor, i.e., a controlled plant. To show the validity of the proposed method, experiments using the controlled plant were conducted to evaluate tracking errors for positioning control with and without the proposed disturbance observer. From the experimental results, it has been confirmed that the proposed disturbance observer can eliminate influence of the friction and is effective to improve positioning accuracy.

**High Precision Control of Ball Screw Driven Stage Using Sharp Roll-off Learning Q Filter**

Tadashi Takemura (University of Tokyo, Japan)
Hiroshi Fujimoto (University of Tokyo, Japan)

Repetitive perfect tracking control (RPTC) is one of repetitive control techniques to achieve high precision positioning. In this paper, RPTC with n-times learning filter is proposed. n-time learning filter has a sharp roll-off property than conventional learning filter. By using n-times learning filter, proposed RPTC can converge tracking error n-times faster than RPTC with conventional learning filter. Simulations show the fast convergence of proposed RPTC. Finally, experiments in ball screw driven stage also show the effectiveness of proposed system.

**Model-Based Feedforward Compensation for Disturbance Caused by Rotational Motion in 2-Dimensional Shaking Table Systems**

Kenta Seki (Nagoya Institute of Technology, Japan)
Makoto Iwasaki (Nagoya Institute of Technology, Japan)

This paper presents a modeling and control approach of 2-dimensional (2D) shaking table systems for earthquake simulators. In the system, rotational moment generated by centroid movement generally deteriorates the motion performance of the table, resulting in the lower reproducibility for the desired earthquake acceleration. In this paper, therefore, a 2D shaking table system with multi-actuators and specimen is mathematically modeled on the basis of geometrical arrangement and equation of motion. Then, feedforward compensators are designed by using a disturbance model to cancel the effects of moment. The proposed approach has been verified by experiments using an laboratory 2D shaking table system.

**Head Positioning Control System Design Based on Dynamic Characteristic of Rolling Friction in HDDs.**

Motohiro Kawafuku (Nagoya Institute of Technology, Japan)
Masato Mizoguchi (Nagoya Institute of Technology, Japan)
Makoto Iwasaki (Nagoya Institute of Technology, Japan)

This paper describe a head positioning controller in HDDs based on a dynamic characteristic of rolling friction. In the control system in HDDs, the head assembly was influenced the effect of several disturbances, e.g. RRO, flutter vibration, force disturbance, and so on. At the force disturbance, it caused by wind force, external shock, tension force of Flexible Printed Circuit, and rolling friction around pivot bearing. In these force disturbance, the influence of the rolling friction is large at positioning in minute area. Therefore, controlling the rolling friction is important at short span seeking motion for the high performance trajectory. In this paper, we present a measuring method for the dynamic rolling friction that considering the inertia force of magnetic head. And we propose a 2 DOF controller design to suppress the effect of the dynamic rolling friction. The effects of the proposal method and controller performance are verified by experimental results.

**A Smoothed GMS Friction Model for Moving Horizon Friction State and Parameter Estimation**

Max Boegli (K.U.Leuven, Belgium)
Tinne De Laet (K.U.Leuven, Belgium)
Joris De Schutter (K.U.Leuven, Belgium)
Jan Swevers (K.U.Leuven, Belgium)

This paper presents a smoothed friction model that closely approximates the Generalized Maxwell-Slip (GMS) model, a multi-state friction model known to describe all essential friction characteristics in presliding and sliding motion. In contrast to the GMS model, which consists of a switching structure to accommodate for its
hybrid nature, the Smoothed GMS (S-GMS) model consists of an analytic set of differential equations well suited for on-line state and parameter estimation, such as in Moving Horizon Estimation (MHE). Efficient on-line state and parameter estimation is essential for model-based friction compensation in order to track friction characteristics changes in time and space. Moreover, MHE is known to better handle model nonlinearities, disturbances and constraints than Extended Kalman Filter (EKF). This paper discusses the implementation of the EKF and MHE estimators for both the GMS and the S-GMS friction models. The benefit of the combination of MHE and S-GMS model is shown.

OS-6-1 Musculoskeletal Structure based Robotics

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<tr>
<th>Leg Space Observer on Biarticular Actuated Two-Link Manipulator for Realizing Spring Loaded Inverted Pendulum Model</th>
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<td>Yasuto Kimura (University of Tokyo, Japan)</td>
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<td>Sehoon Oh (University of Tokyo, Japan)</td>
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<td>Yoichi Hori (University of Tokyo, Japan)</td>
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This paper proposes kinematics and a control algorithm to control a two-link manipulator to simulate a spring loaded inverted pendulum (SLIP). End-effector kinematics is derived in the reference frame that is defined along the axis that connects the first joint and the end-effector. The derivation of this kinematics reveals that a biarticular actuator is suitable for this kinematics. Based on this kinematics, a disturbance observer is designed in the same reference frame. This disturbance observer removes the unnecessary inertia coupling without calculation of Jacobian matrix.

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<th>Force Control of Musculoskeletal Manipulator</th>
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<tr>
<td>Ahmad Zaki Shukor (Yokohama National University; Japan)</td>
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<tr>
<td>Yasutaka Fujimoto (Yokohama National University; Japan)</td>
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This paper presents force control of musculoskeletal manipulator. The kinematic and dynamic properties are shown to address the presence of environmental contact with the manipulator. From this contact, the force control schemes were explored, by comparing between monoarticular-only structure and biarticular structure manipulator. Force control schemes were divided into independent muscle control, end effector step force command, and muscular viscoelasticity control.

<table>
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<tr>
<th>Development of a Physical Therapy Robot for Rehabilitation Databases</th>
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<td>Tomonori Yokoo (Saitama University, Japan)</td>
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<td>Toshiaki Tsuji (Saitama University, Japan)</td>
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<td>Sho Sakaino (Saitama University, Japan)</td>
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<td>Shigeru Abe (Saitama University, Japan)</td>
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With increasing demands for rehabilitation, the need for physical therapy robots is also increasing. This paper proposes the construction of a rehabilitation database inspired with medical cloud technologies. We discuss the possibility of establishing a new validation methodology by generating a database based on the data collected using rehabilitation equipment. In this research, data was obtained by rehabilitation equipment and statistical processing was applied to the data to investigate an example of a validation method. The experimental results suggest that improvement of tracking property of subjects is much larger than improvement of maneuverability.

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<tr>
<th>Analysis of Actuator Redundancy Resolution Methods for Bi-articularly Actuated Robot Arms</th>
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<tr>
<td>Valerio Salvucci (University of Tokyo, Japan)</td>
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<td>Sehoon Oh (University of Tokyo, Japan)</td>
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Bi-articular actuators — actuators that span two joints — are rising interest in robot application because they increase stability, optimize force production, and reduce the non-linearity of the end effector force as a function of force direction. In this paper, we propose an approach to resolve actuator redundancy for bi-articularly actuated robot arms in which the three actuators produce maximum joint actuator torques that differs among each other. A closed form solution based on the infinity norm is derived. The proposed infinity norm based approach is compared with the conventional 1-norm and 2-norm based methods. Under the same actuator limitations, the maximum end effector force produced with the proposed method is significantly greater than the one produced by the conventional methods. The proposed closed form solution is suitable for redundant systems with three inputs and two outputs, bringing the advantage of an higher maximum output without the need for iterative algorithms.

Total Harmonic Distortion of Haptic Modal Information for Analysis of Human Fingertip Motion
Tomoyuki Shimono (Yokohama National University; Japan)
Yoshiyuki Hatta (Yokohama National University; Japan)
Naoki Motoi (Yokohama National University; Japan)
This paper proposes an evaluation index for the analysis of the motion complexity in parallel multi-degrees-of-freedom (MDOF) haptic system. Firstly, the modal decomposition based on discrete Fourier series expansion (DFS) is described. Modal information expresses a motion element that corresponds to a specific physical action. The modal information can be defined by the Fourier coefficients. This paper proposes a total harmonic distortion (THD) of the haptic modal information as a haptic motion index. The utility of the proposed index is confirmed from the experimental results on the bilateral motion control of MDOF haptic system.

Force Control of a Spiral Motor and Its Application to Musculoskeletal Biped Robot
Yasutaka Fujimoto (Yokohama National University; Japan)
Tsubasa Suenaga (Yokohama National University; Japan)
Yuuki Wakayama (Yokohama National University; Japan)
Kengo Sawai (Yokohama National University; Japan)
Ahmad Zaki Shukor (Yokohama National University; Japan)
This paper proposes force control of a spiral motor in combination with zero-power magnetic levitation control. The motor has a helical-shape mover, which moves in a helical-shape stator without contact. Due to the manufacturing process, the actual spiral motor contains fluctuation of neutral point of the air-gap displacement depending on the mover rotation angle. The d-axis current remain a finite value and copper loss arises even when the mover is located at the center between the stator cores. Zero-power magnetic levitation control is proposed to solve this problem. The proposed control is experimentally verified. In addition, a model of a musculoskeletal biped robot equipped with spiral motors are introduced.

ED-1 Electric Drives

Event-Driven Approach to Control Mechatronic System with FPGA
Robert Horvat (FERI, University of Maribor, Slovenia)
Karel Jezernek (FERI, University of Maribor, Slovenia)
Milan Ćurkovič (FERI, University of Maribor, Slovenia)
A mechatronic system consists of a mechanical system and electric actuators. The event-driven control of a mechatronic system was implemented on a field-programmable gate-array (FPGA) platform. The supervisor provides robust, safe, and transparent control, where the FSM defines all the possible directions for implementation. In order make supervisor more transparent, the FSM was divided into three main parts, with three main colours (green, yellow and red - semaphore). These colours indicate the condition of the system. The supervisor was upgraded with a Graphic user interface (GUI) with indicators that directly show the state of the FSM. The GUI includes additional logical I/O signals, in order to make system more useful. The supervisor is
executed parallel with the basic motor control on the FPGA. This paper presents the robust current controller of the brushless ac (BLAC) motor, upgraded with a classical PI velocity controller. The application of the proposed ECA-based method is illustrated using the example of the FSM motion control of a BLAC motor with integrated I/O signals

**Fault-tolerant Control of a Wind Turbine with a Squirrel-cage Induction Generator and Stator Inter-turn Faults**
Vinko Lešić (University of Zagreb, Croatia)
Mario Vašak (University of Zagreb, Croatia)
Nedjeljko Perić (University of Zagreb, Croatia)
Gojko Joksimović (University of Montenegro, Montenegro)
Thomas Wolbank (Vienna University of Technology, Austria)

Faults of wind turbine generator electromechanical parts are common and very expensive. This paper introduces a fault-tolerant control scheme for variable-speed variable-pitch wind turbines that can be applied to any type of generator. We focus on generator stator isolation inter-turn fault that can be characterized before triggering the safety device. A simple extension of the conventional control structure is proposed that prevents the fault propagation while power delivery under fault is deteriorated as less as possible compared to healthy machine conditions. Presented fault-tolerant control strategy is developed taking into account its modular implementation and installation in available control systems of existing wind turbines to extend their life cycle and energy production. Simulation results for the case of a 700 kW wind turbine are presented.

**Design and Realization of Hybrid Drive with Supercapacitor and Power Flow control**
Marijan Španer (FERI Uni Maribor, Slovenia)
Andreja Rojko (FERI Uni Maribor, Slovenia)
Karel Jezernik (FERI Uni Maribor, Slovenia)

Hybrid electric vehicles are one of the most effective solutions to improve our environment and also one of the few of such products which are actually commercially produced. With the improved energy storage systems and control algorithms, such vehicles can further gain at the applicability and consequently at the popularity. In this paper, a design and control of the elements of the hybrid vehicle propulsion system, with an emphasis on supercapacitor as the peak energy storage unit, is presented. The propulsion system is dimensioned for a light delivery vehicle. In order to simplify testing, a laboratory test rig was built rather than using the complete vehicle. Through simulations and experiments a significant improvement of the energy storage system is confirmed after adding the supercapacitor to the battery. The experiments also confirm the advantages of energy flow management based on the stabilization of the common DC bus voltage

**Disturbance estimation for Sensorless PMSM Drive with Unscented Kalman Filter**
Dariusz Janiszewski (Poznan University of Technology, Poland)

This paper describes a study and experimental verification of sensorless control of Permanent Magnet Synchronous Motor. There are proposed novel estimation strategy based on the Unscented Kalman Filter, using only the measurement of the motor current for on-line estimation of speed, rotor position and disturbance – load torque. Information about the load is important for complex drive control systems like robot arm. It is seldom obtained by estimation way especially in sensorless systems. Used Kalman filter is an optimal state estimator and is usually applied to a dynamic system that involves a random noise environment. Control structure with unscented algorithm, in real time requires a very efficient signal processor. Experimental results have been carried out to verify the effectiveness and applicability of the novel proposed estimation technique.
Frequency analysis of mechanical resonance in direct drive
Dominik Luczak (Poznan University of Technology, Poland)

This paper presents analysis of mechanical resonance in direct drive servo-mechanical systems. For this purpose frequency analysis was used. Motor speed signal was analysed by Fourier transform to find mechanical resonance frequencies. Presented methods were verified by simulation.

Parameter Estimation of Two-Mass Mechanical Loads in Electric Drives
Seppo Saarakkala (Aalto University, Finland)
Tuomo Leppinen (ABB Drives, Finland)
Marko Hinkkanen (Aalto University, Finland)
Jorma Luomi (Aalto University, Finland)

This paper presents a method for parameter estimation of two-mass mechanical loads. A discrete-time polynomial model with an output error (OE) structure is used in parameter estimation. Four different identification setups are obtained when open-loop estimation and various possibilities of choosing the input and output signals in closed-loop estimation are considered. All four setups are analyzed, and the identifiabilities are compared. It is discovered that all four identification setups can be used to obtain reasonable parameter estimates.

Drivetrain of Electric Car: Development of Virtual Laboratory for E-learning
Venugopal Prasanth (Delft University of Technology, The Netherlands), Pavol Bauer (Delft University of Technology, The Netherlands), Pšenáková Ildikó (Univerzita Konštantína Filozofa, Slovakia)

Virtual laboratories that animate scientific phenomena are becoming an increasingly popular method to teach students. Electrical engineering is considered difficult to understand as it demands a high level of imagination. This difficulty can be dealt with to a large extent by developing visual aids in the form of animations. Animations can help students to grasp the idea quickly and therefore can serve as an effective aid for the learning process. This paper deals with the development of such a teaching aid to tackle a particular problem in Electrical Drives and Power Electronics (ED&PE). The problem is that of the electrical drive train of a hybrid electric vehicle (HEV) that can regenerate power during braking or whenever required (Plug-in HEV, PHEV). This paper attempts to give a step-by-step insight into the various design choices, the operation of the converters and their controls, the learning objectives and finally the development of the graphic multimedia for this drive train.

OS-2-3 Smart Precise Motion Control – Industrial applications of precision motion control

Anti-sway Sliding-mode with Trolley Disturbance Observer for Overhead Crane system
Jadesada Maneeratanaporn (Keio University, Japan)
Toshiyuki Murakami (Keio University, Japan)

Moving the suspended load along a predefined trajectory as fast as possible is not an easy controlling task due to the residual swing at the end of traveling. In this paper, the overhead crane is fully automated with the high speed trajectory. Robust scheme, namely anti-sway sliding-mode with trolley disturbance observer (DOB) is implemented with overhead crane systems. The anti-sway sliding-mode is specially designed for underactuated nonlinear systems, which is derived from Lyapunov law. The asymptotic stability of switching function is proved theoretically. The controller can eliminate the error toward their sliding surfaces. Furthermore, trolley disturbance observer is also implemented to enhance the robustness. An obvious advantage of this kind of controller is based on simple control scheme however it can guarantee the robustness, speed convergence and swing suppression. In this paper, Experiment results are presented to show the superiority of the anti-sway
sliding-mode with actuator's disturbance observer by comparing the effectiveness with PD controller assisting with Lyapunov based anti-sway controller and anti-sway sliding mode without disturbance observer. Not only that the filtering technique is also employed to eliminate chattering effect.

**High Accurate Modeling of Vehicle Dynamics Considering Three-Dimensional Rotating Motion**

Wataru Kubota (Nagoya Institute of Technology, Japan)
Motohiro Kawafuku (Nagoya Institute of Technology, Japan)
Makoto Iwasaki (Nagoya Institute of Technology, Japan)
Hirotaka Tokoro (DENSO Corporation, Japan)

This paper proposes a novel modeling methodology of vehicle dynamics to reproduce the actual three-dimensional rotating motion. In the proposed approach, a rigid body of vehicle is physically modeled with constraint force, where Euler's equation of motion is applied to numerically calculate rotating behaviors around the center of gravity of the body, under a modeling framework of motion of multibody system. In the numerical processing, the three-dimensional rotating angular velocity around the center of gravity can be calculated by a summation of angular momentum generated by external moment and an inertia moment tensor of the rigid body. Effectiveness of the proposed approach has been verified by comparative numerical simulations with experimental waveforms using a test passenger vehicle.

**Vibration Control of Flexible System With Communication Delay Using Wave Compensator**

Eiichi Saito (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

Recently, teleoperated robot has been researched for working in ultimate environment actively. Developing performance of teleoperated robot, it will be possible for human to work in such a ultimate environment with safety. However, in the actual case, as gears are used for amplifying output, stiffness of connection part reduces and vibration occurs. Moreover, communication delay causes vibration, too. In addition, in the worst case, the system becomes unstable. Therefore, in this paper, for suppression of the vibration, vibration control using wave compensator is proposed. In the proposal, there are two important control structures. Firstly, reflected wave in the resonant system is eliminated by reflected wave rejection. Transfer function of wave equation without reflected wave is composed of a time delay. Therefore, resonant system can be regarded as time delay system. Next, vibrations from flexible mechanism and communication delay are simultaneously suppressed by wave compensator. Finally, the validity of the proposal is verified by experimental results.

**FPGA Implementation of the Bilateral Control Algorithm for a High Performance Haptic Teleoperation**

Marko Franc (Isomat d.o.o., Slovenia)
Aleš Hace (University of Maribor, Slovenia)

This paper deals with a haptic teleoperation, that can significantly improve the execution over a wide area of tasks. The latter can be found in a medicine, military, space exploration and many others. The paper describes the control algorithm implementation for a high performance haptic teleoperation. The algorithm is tested by a 2-DOF experimental haptic laboratory system. The Field Programmable Gate Array (FPGA) contributes to the bilateral teleoperator performance, therefore, transparency, stability, and robustness can be increased.

**Force Sensorless Pressure Control Considering Nonlinear Friction Phenomenon for Electric Injection Molding Machine**

Ryo Furusawa (Nagaoka University of Technology, Japan)
Kiyoshi Ohishi (Nagaoka University of Technology, Japan)
Koichi Kageyama (Niigata Machine Techno CO., LTD, Japan)
Masaru Takatsu (Niigata Machine Techno CO., LTD, Japan)
Shiro Urushihara (Kagawa National College of Technology, Japan)

Currently, most plastic products are manufactured using injection molding machines. The quality of products produced this way depends largely on the injection force. In the force control system of a typical injection
molding machine, force information from the machine’s environment is obtained by a force sensor. However, these sensors have several disadvantages, which include signal noise, sensor cost, and a narrow bandwidth. Thus, sensorless force detection methods are desirable. The use of a reaction force observer, based on the two-inertia resonant model, has been proposed. However, this method is inaccurate due to the influence of nonlinear friction phenomenon. We have previously proposed a new injection force estimation method based on a high-order reaction force observer (HORFO), which is not significantly influenced by the nonlinear friction phenomenon. In this paper, an automatic parameter-switching HORFO (APSRFO) is proposed to improve the estimation accuracy of HORFO. Moreover, this paper evaluates the possibility of a sensorless force control system using the proposed APS-RFO.

**Study on re-adhesion control by monitoring excessive angular momentum in electric railway tractions**

Takafumi Hara (University of Tokyo, Japan)
Takafumi Koseki (University of Tokyo, Japan)

Suppression of slip and reduction of friction between rail and wheel are important in railway systems. This paper proposes a novel slip re-adhesion control based on the excessive torque and excessive angular momentum for 4 axle and 2 truck model (1C2M, 1 inverter 2 motor drive system). Effectiveness of the proposed method has been confirmed by mathematical analysis. Furthermore, the proposed method was evaluated by two performance indicators, frictional force reduction and effective utilization of adhesive force. As a result, adhesion characteristic of the proposal method was 7.04 % better than the conventional method. In addition, loss friction force around driving wheel remained unchanged.

**OS-6-2 Musculoskeletal Structure based Robotics**

**Model-based Compensation of Wire Elongation for Tendon-driven Rotary Actuator**

Yuki Saito (Keio University, Japan)
Takahiro Nozaki (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

Tendon-driven rotary actuators are utilized for bilateral control. However, tendon-driven systems have a problem. When force is applied to wires, polyethylene lines are extended. In this paper, a model-based compensation method of the wire elongation for tendon-driven rotary actuators is proposed. In proposed method, the wires are modeled based on Voigt model which is composed of an elastic spring and a viscous damper. Coefficients of elasticity and viscosity are identified by offline experiment using constant force command. Then, wire elongations are estimated by the wire model using identified values. The proposed method was applied to angle control and bilateral control of tendon-driven rotary actuators. Then the performances of wire elongation compensation were compared. The validity of the proposed method was confirmed by experiments. Angle error caused wire elongation was reduced by proposed method.

**A Method of Joint Torque Control for a Tendon-Driven System**

Uichiro Nishio (Keio University, Japan)
Takahiro Nozaki (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

It is hoped that robots are utilized in environments where human lives. Robots should work safely and perform complicated tasks. For safety, precise force control and lightweight mechanism are important because robots contact with human. In order to perform complicated tasks, multi-degrees-of-freedom system is needed. Tendon-driven system is able to achieve precise motion control and complicated tasks. In this system, wires are utilized as force transmission. Therefore, the system can achieve lightweight robot and can generate large joint torque. However, each joint torque interferes mutually because the tendons are attached to each link. Tendon tension must be kept over zero because the tendons can only generate traction force. In this paper, an inverse matrix of joint control Jacobian matrix with tension control was proposed in order to achieve tension control and torque
control. This inverse matrix contains two conditions. One is the condition of joint torque control. The other is the condition that the minimum value of tendon tension is kept zero. In addition, the minimum value of tendon tension can be easily changed by bias force. Simulation results and experimental results show the validity of the proposed method.

Application of Tension Control into Linear Motor-Actuated Cable Differential-Driven Joint
Tomoko Kawase (Keio University, Japan)
Keita Shimamoto (Keio University, Japan)
Kazuki Tanida (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)
Tendon-driven systems are one of efficient methods to downsize robots. This paper discusses application of tension control into a joint using cable differential. Cable differential is mechanism which allows two-degrees of freedom (DOF) in one joint. Controllers for the cable differential-driven joint are proposed in the paper. The joint is actuated by four linear motors. The controllers are designed regarding the tendon-driven system as a redundant system. In this way, tension control is considered as a task in the null space. This makes implementation of tension control stereotypical.

Function Separation for 2-DOF Haptic Surgical Forceps Robots driven by Multi Drive Linear Motors
Kazuki Tanida (Keio University, Japan)
Takahiro Mizoguchi (Keio University, Japan)
Fumiya Mitome (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)
2-DOF haptic surgical multi drive robot is driven by multi drive linear motors, and does not separate hand function (manipulating mode) and arm function (grasping mode) of the human motion mechanically. Conventional method has one problem. When the operator want to grasp an object, he have to drive forceps open. This make operator difficult to use forceps finely and powerfully. A proposed method separates two function of position in control. Conventional of grasping/manipulating control uses modal transformation matrix for master or slave robots to achive bilateral control between different structural. The proposed method use modal transformation matrix both master and slave robots between same structure. Moreover, the proposed method enables us to operate like actual forceps than conventional method. The validity of the proposed method is varified by experiments.

A Numerical Simulation Using The Optimal Control Can Estimate Stiffness Profiles of A Monkey Arm during Reaching Movements
Yuki Ueyama (Tokyo Institute of Technology, Japan)
Eizo Miyashita (Tokyo Institute of Technology, Japan)
To elucidate a law of the brain how to constrain dimensions of freedom to control the body would be beneficial to robotics engineering that deals with a humanoid robot. We estimated joint stiffness of a female Japanese monkey (Macaca fuscata) during arm reaching movements and carried out a numerical simulation experiment. The estimated stiffness showed high value at movement onset and movement end, and decreased at mid point of the movement. These characteristic patterns were reproduced by the numerical simulation experiment of a 2-link 6-muscle arm model using an approximately optimal feedback control. Although the arm model was a redundant system with multiple dimensions of freedom, the optimal control was able to solve the redundancy problems by optimizing a task relevant cost function. We suggest that the brain may control the body in accordance with the optimal control law.

Model-based compensation of hysteresis in the force characteristic of pneumatic muscles
Dominik Schindele (University of Rostock, Germany)
Harald Aschemann (University of Rostock, Germany)
This paper presents a compensation strategy for the hysteresis in the nonlinear force characteristic of pneumatic muscles. For a dynamical modelling of the hysteresis, the generalised Bouc-Wen model is employed. This model allows for the representation of highly asymmetric hysteresis. The parameters of the Bouc-Wen model are identified by measurements. An existing control structure for a high-speed linear axis actuated by pneumatic muscles is extended by the Bouc-Wen model with the identified parameters for compensation of the hysteresis. Experimental results from an implementation on a test rig show the efficiency of the proposed compensation strategy.

HR-1 Humanoid Robots I

Disturbance Observer that estimates External Force acting on Humanoid Robots
Kenji Kaneko (AIST, Japan)
Fumio Kanehiro (AIST, Japan)
Mitsuharu Morisawa (AIST, Japan)
Eiichi Yoshida (AIST, Japan)
Jean-Paul Laumond (LAAS-CNRS, France)

This paper presents an external force observer that estimates the external force acting on a biped humanoid robot, such as a collision force with a human or with an object. Since biped humanoid robots balance themselves on a limited area with foot soles, the detection of external force is important to realize for a stable balance controller for humanoid robots working in a real environment. In the proposed observer, the external force is estimated using inertial sensors and foot force sensors based on simple but efficient modeling of the forces applied to the robot. This paper also shows the experiments of the proposed external force observer using a real humanoid robot HRP-2. The experimental results show that the proposed observer has satisfactory performance to estimate the external force with sufficient response and accuracy.

Falling Risk Evaluation Based on Plantar Contact Points for Biped Robot
Hisashi Ono (Keio University, Japan)
Takahiko Sato (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

In recent years, humanoid robot has been expected in various fields because of the shape and architecture of humanoid robot and aging of society. It is important that robot does not harm human beings so that we coexist with robot. Therefore, a lot of researchers have studied about falling. Zero-Moment Point (ZMP) is most widely used as a stability indicator of biped robot. ZMP, however, is not unsuitable for falling indicator because of behavior of ZMP. On the other hands, Foot-Rotation Indicator (FRI) is useful when robot falls. However, FRI point does not include content that whether robot keeps a balance on boundary surface of falling. In addition, FRI point is complicated and it is hard to calculate. A permissible amount of falling risk evaluation, therefore, is presented in this paper. This permissible amount is calculated by plantar contact points of the robot, acceleration of center of gravity and reaction force. During robot is walking or standing, the falling risk is evaluated by this permissible amount. This method is applied for a condition of robot before robot falls. Proposed method is evaluated by the experimental results.

Stable Landing Method for Biped Robot by Using Switching Control
Kenta Sasahara (Yokohama National University; Japan)
Naoki Motoi (Yokohama National University; Japan)
Tomoyuki Shimono (Yokohama National University; Japan)
Atsuo Kawamura (Yokohama National University; Japan)

This paper proposes the switching control method to realize stable landing for a biped robot. If the landing of the biped robot is unstable, the robot may fall down. Therefore, it is necessary for the biped robot to realize stable landing. In order to achieve the stable landing, force controller should be implemented at the moment of landing.
Since force control enables the sole to softly contact the ground. If the landing state becomes stable, control method needs to change position control for the biped robot moving. In other words, the controller should be switched according to the contact condition between the sole and the ground. Therefore, switching control method which consists of position control and force control is proposed. Zero Moment Point (ZMP) is used as index to switch the controller. Position control is applied when ZMP exists in the area around the center of the foot. Force control is used when ZMP exists around the edge of the foot. The validity of the proposed method is confirmed from the simulation results by using the model of inverted pendulum with a sole.

Gyroscope Assistance for Human Balance
Dustin Li (KUSTAR, United Arab Emirates)
Heike Vallery (KUSTAR, United Arab Emirates)

Falls are an urgent challenge in our aging society, and balance dysfunction is a major risk factor. Current robotic technology that assists human locomotion, however, aims at versatile functionality, particularly in the assistance of weak muscles. Such versatile design leads to heavy, bulky devices that are impractical in daily life for most elderly subjects. In this paper, we investigate the use of minimalistic robotic technology that exclusively focuses on stabilizing human balance during gait. This task-specific device is novel in its combination of portability and simplicity. Our initial simulations show that it is possible to return a person to a vertical position from an engagement angle of 10 degrees from vertical.

Verification of biped robot using point-contact type foot with springs for walking on rough terrain
Moyuru Yamada (Toyohashi University of Technology, Japan)
Shigenori Sano (Toyohashi University of Technology, Japan)
Naoki Uchiyama (Toyohashi University of Technology, Japan)

This study introduces a biped robot designed with a point-contact type foot with springs (PCFS) and proposes a control method for stable walking on rough terrain. Realizing stable walking on rough terrain is important because biped robots are expected to assist humans not only in flat and known environments but also on rough ground surfaces with unknown terrain variances. The PCFS is a new foot system that was proposed in our previous study, which realizes stability on complex ground surfaces and suppresses impact force during foot landing. To adjust a foot position and posture in response to the declination between the predicted and actual ground surfaces, we proposed a landing controller for uncertain rough terrain. In this study, we also propose a dynamic walking pattern for the biped robot and demonstrate the effectiveness of the proposed method via simulation results.

Towards integrated walking and jumping motion planning in complex environments: Jumping trajectory generation
Kirill Van Heerden (Yokohama National University; Japan)
Atsuo Kawamura (Yokohama National University; Japan)

This paper presents the initial research of creating a framework by which a biped robot can make a navigation plan in a obstacle filled environment by performing both walking and jumping motions. In particular this paper focuses on automatically creating a jumping trajectory based on the distance that the robot is required to jump. This jumping trajectory considers angular momentum so as to reduce backwards jumping and spinning of the base in the air, this is done with the Eulerian ZMP resolution method (EZR). Additionally this trajectory also considers compliance at the landing foot to avoid manipulator damage while ensuring that the robots support foot is extended just the right distance to let a inverted pendulum model to reach the top with zero kinetic energy remaining. The path planner is based on the A-Star path planning algorithm. The navigation plan also considers finding a path which is sufficiently straight prior to the moment of jumping so that the robot can build up the required linear momentum to execute the jump. The ultimate goal is to create a framework which can consider path planning with various types of motion.
BC-1 Bilateral Control I

An Approach to Controller Design of Bilateral Control with Dimensional Scaling
Takahiro Kosugi (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

In the field of teleoperations, visual or haptic information is utilized in order to obtain the situation at a remote side. Conventionally, various teleoperations have been constructed and are mainly based on visual information. However, tactile sensation which is important information when devices are in contact with environment is not able to be obtained with this approach. To tackle this problem, research on haptic transmission in the real-world by using a bilateral control has been attracting attention. For transmitting haptic information, a master-slave system should be constructed. As for the configuration, it does not always the same structure. From this point of view, teleoperation systems are classified into two types of systems. One is a fixed type system and the other is a mobile type system. Particularly, this paper focuses on the latter type system which has the characteristic that the synchronization must be attained between the different types of signals with regard to the dimension (e.g. between position and velocity) while the force transmission is also realized. In response to this requirement, a bilateral control with dimensional scaling on the basis of modal decomposition was proposed. However, the structures of controllers in the modal space have not been fully analyzed. Therefore, this paper clarifies the design procedure of the bilateral control with dimensional scaling taking into account the interference between the common and differential modes. Experimental results show the validity of the controller design.

Position/Force Decoupling for Micro-Macro Bilateral Control based on Modal Space Disturbance Observer
Takahiro Nozaki (Keio University, Japan)
Takahiro Mizoguchi (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

A four channel bilateral control is one of the teleoperation techniques. In this control, position and force have to be controlled precisely. However, there is some interference between position control and force control, if the inertia of the master robot is different from slave side. In this paper, a diagonalization method by using modal space observer is proposed for the sake of position/force decoupling. This method diagonalizes an equivalent mass matrix in a modal space. Operationality and reproducibility, which are performance indices, are indicated. Furthermore, root locus plots are shown to analyze the stability. The validity of the proposed method is verified by experiments. In other words, the decoupling effect of the diagonalization method is higher than conventional method, and more stable.

Separated Master System to Decrease Operational Force of Bilateral Control
Haruya Sato (Keio University, Japan)
Takahiro Mizoguchi (Keio University, Japan)
Fumiya Mitome (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

This paper proposes separated master system to decrease operational force of bilateral control in free motion. Operational force in bilateral control is not desirable because it prevent accurate reproduction of remote environmental force. Thus to decrease operational force is important. The master system consists of a grip part and an actuator part. A human operator manipulates the grip part. In free motion, both the actuator part of master robot and the slave robot track the grip part. With separating actuator, human operator feels fewer inertial force and friction when in free motion. When the slave robot contacts an object, the grip part contacts the actuator part and the operator feels reaction force from the object. The actuators tracked grip motion and the law of action and reaction was realized in experiment.
A Novel Dimensional Scaling Bilateral Control for Realization of Mobile-Hapto
Shunsuke Yajima (Keio University, Japan)
Wataru Yamanouchi (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

This paper proposes a novel dimensional scaling bilateral control for mobile-hapto. The dimensional scaling bilateral control realizes force feedback between the master and the slave with different motion areas. By this system, an operator can manipulate velocity of the slave, and feel reaction force at the slave. For realizing this system, force and position responses of the master and the slave are transformed to a modal space. And force and position controllers are constructed in the modal space. In the conventional method, however, a precise bilateral controller is not achieved because the dynamics in the modal space is not considered. Therefore, in this paper, the dynamic behaviors in the modal space is described, and a decoupling control system with the disturbance observer in the modal space is realized by the proposed method. Finally, the validity of the proposal is verified by simulation and experimental results.

Transparency Analysis of Motion Canceling Bilateral Control under Sensing Constraints
Yu Nakajima (Keio University, Japan)
Takahiro Nozaki (Keio University, Japan)
Takahiro Mizoguchi (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

Motion canceling bilateral control (MCBC) is a method to synchronize motion of a teleoperation robot and a target, while an operator can obtain tactile sensation of the remote target. This system helps the operator by taking a task and reduces his/her workload. Unfortunately, the transparency is deteriorated due to the operational force caused by the motion of the target. This effect is caused by the discreteness and delay in external sensors essential for MCBC. However, the relationship between the transparency and those sensing constraints is not clarified yet. Therefore in this research, the frequency characteristics of the transparency for the MCBC are analyzed in the following three basis: type of holds, sampling period, and stiffness of the target. The analytical result suggested following three behaviors in the transparency of the MCBC: 1. A first order hold showed better performance compared with a zero order hold, but it has a peak gain near the Nyquist frequency, 2. Shorter sampling period improves the performance, 3. Contacting hard target deteriorate the performance. The validity of analysis was verified by the experimental results.

Scaling Bilateral Controls with Impedance Transmission Using Transfer Admittance
Takahiro Mizoguchi (Keio University, Japan)
Takahiro Nozaki (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

Scaling bilateral control is a method to extend human ability by using master and slave robot. Position scaling extends working space of human, force scaling extends sensitivity of human. This technology is useful when slave robot is larger in size compared with the master robot. In general, correct environmental impedance, such as softness or hardness of the object, cannot be transmitted in scaling bilateral control due to mismatch of force scaling and position scaling in the bilateral control. However, correct environmental impedance is necessary for the safe operation, especially in scaling bilateral control where mass of robot tends to become large. This paper proposes a method of transmitting environmental impedance in position scaling bilateral control. Position scaling is focused for the sake of extending working space of operator when slave robot has larger working space compared to master robot. There exist two methods to scale position in bilateral control; scaling with constant coefficient and scaling with dimension variation. Conventionally, neither of these achieves correct impedance transmission. Proposed method can be applied to both position scaling methods with the same procedure and achieves impedance transmission by using property of gyrator type bilateral control. The effect of the proposal is verified through simulation and experiment.
### RO–1 Robotics I

#### Experiment-Based Kinematic Validation of Numeric Modeling and Simulated Control of an Untethered Biomimetic Microrobot in Channel

Ahmet Fatih Tabak (Sabanci University, Turkey)
Serhat Yesilyurt (Sabanci University, Turkey)

Modeling and control of swimming untethered microrobots are important for future therapeutic medical applications. Bio-inspired propulsion methods emerge as realistic substitutes for hydrodynamic thrust generation in micro realm. Accurate modeling, power supply, and propulsion-means directly affect microrobot motility and maneuverability. In this work, motility of bacteria-like untethered helical microrobots in channels is modeled with the resistive force theory coupled with motor dynamics. Results are validated with private experiments conducted on cm-scale prototypes fully submerged in Si-oil filled glass channel. Li-Po battery is utilized as the on-board power supply. Helical tail rotation is triggered by an IR remote control. It is observed that time-averaged velocities calculated by the model agree well with experimental results. Finally, time-dependent performance of a hypothetical model-based position control scheme is simulated with upstream flow as disturbance.

#### Miniaturized Modular Manipulator Design for High Precision Assembly and Manipulation Tasks

Emrah Deniz Kunt (Sabanci University, Turkey),
Ahmet Teoman Naskali (Sabanci University, Turkey),
Asif Sabanovic (Sabanci University, Turkey)

In this paper, design and control issues for the development of miniaturized manipulators which are aimed to be used in high precision assembly and manipulation tasks are presented. The developed manipulators are size adapted devices, miniaturized versions of conventional robots based on well-known kinematic structures. 3 degrees of freedom (DOF) delta robot and a 2 DOF pantograph mechanism enhanced with a rotational axis at the tip and a Z axis actuating the whole mechanism are given as examples of study. These parallel mechanisms are designed and developed to be used in modular assembly systems for the realization of high precision assembly and manipulation tasks. In that sense, modularity is addressed as an important design consideration. The design procedures are given in details in order to provide solutions for miniaturization and experimental results are given to show the achieved performances.

#### Derivation of Nonlinear Dynamic Model of Novel Pneumatic Artificial Muscle Manipulator with a Magnetorheological Brake

Hiroki Tomori (Chuo University; Japan)
Yuichiro Midorikawa (Chuo University; Japan)
Taro Nakamura (Chuo University; Japan)

An artificial rubber muscle was used as an actuator in the present study because it was safe for the muscle manipulator to come into contact with the human body. However, this actuator vibrates and can cause late responses because of the air pressure that is applied to the manipulation. We have built a magnetorheological (MR) brake that uses MR fluid with fast response into the joint to control the vibration. In this paper, we have described the manipulator's dynamic characteristics by construction of a model for improvement of the control performance of the MR brake. Furthermore, a simulation was performed using the model and efficient braking by the MR brake was achieved.
### Two Approaches to Bounded Jerk Trajectory Planning

Branislav Konjević (HEP Plomin, Croatia)
Mario Punčec (University of Applied Science, Varaždin, Croatia)
Zdenko Kovačić (University of Zagreb, Croatia)

This paper presents two different approaches to trajectory planning that provide boundedness of position, velocity, acceleration and jerk. To achieve that goal on all segments of the planned trajectory, the first approach combines fifth-order and fourth-order polynomials, while the second one separates a velocity profile from a given path. Using a minimal path traversal time criterion for both approaches, the methods were tested and verified on a selected trajectory for a three degrees of freedom (DOF) planar articulated robot.

### Workspace analysis of parallel mechanisms through neural networks and genetic algorithms

Zeynep Ekicioğlu Kuzeci (Yildiz Technical University, Turkey)
Huseyin Alp (ISBAKInc, Turkey)
Vasfi Emre Omurlu (Yildiz Technical University, Turkey)
Ibrahim Ozkol (Istanbul Technical University, Turkey)

Stewart Platform Mechanism (SPM) is a type of parallel mechanism (PM) which has 6 degrees of freedom. Due to features like precise positioning and high load carrying capacity, PMs have been used in many areas in recent years. But relatively small workspace of the mechanism is the major disadvantage. This paper aims to improve a method for PM workspace analysis in which structure of Artificial Neural Networks (ANNs) which was used to analyze 6x3 SPM’s workspace is determined by Genetic Algorithms (GA). The network structure of ANNs and weights, biases, are very effective on the success of the network. Therefore, calculation of these values and appropriate structure by trial and error, causes too much loss time. To prevent the loss time and to determine the suitability of the structure, a developed GA algorithm is used and tested in simulation environment, are made possible with developed GA program. Successful results of reinforced ANN by GA algorithm are achieved comparing to bold ANN structure.

### Fuzzy Controller Scheduling for Robotic Manipulator Force Control

Mireia Perez Plius (Sabanci University, Turkey)
Metin Yilmaz (Sabanci University, Turkey)
Utku Seven (Sabanci University, Turkey)
Kemalettin Erbatur (Sabanci University, Turkey)

Force control of robotic manipulators is becoming more and more important in applications that involve interaction with the environment. Depending on the nature of the task at hand, different control algorithms can be suitable to be implemented. In this paper the task of reaching an object by the robot tool and applying a constant force on it is considered as a case study. This task is one of the typical manipulation operations. A fuzzy logic scheduling approach, which smoothly changes the control action between two force control schemes, is proposed. The first force control method is admittance control, which is suitable to be used in the phase of approaching the work piece. The second one is an explicit force control strategy, integral force control, suitable for force regulation when the manipulator tool is in contact with the work piece. The fuzzy controller scheduling approach is tested via experimental work on a direct drive SCARA-type manipulator. It is also compared with a crisp controller switching method. Experiments are carried out with fixed and free-to-move work pieces. The results validate that the proposed fuzzy transition has advantages over a crisp switching between controllers.

### CO–2 Control II

#### Position Control of a Seesaw like Platform by Using a Thrust Propeller

Erol Uyar (Dokuz Eylul University, Turkey)
Turgay Akdogan (Dokuz Eylul University, Turkey)
Onur Keskin (Dokuz Eylul University, Turkey)
Lutfi Mutlu (Dokuz Eylul University, Turkey)

This paper presents the design and position control of a seesaw like supported beam which angular motion is measured by an encoder and controlled by the draft force of a propeller at end of the beam. After the general mechanical design and modelling the system, dynamic equations and parameters are investigated and all parts are drawn in Solid Works, so that the real weights and Inertias for the simulation of the motion and a real implementation with reasonable control application could be done. Classic control algorithms such as P, PI, Pd and PID are applied to the real model with various parameters and the obtained results are compared. On the other hand a MATLAB model of the system is derived and simulation results of this model are then compared with real implementation results. Very closed results approved the success of the model with real implementation.

Interpolated gain-scheduled controllers for an Over-head Crane
Keivan Zavari (K.U.Leuven, Belgium)
Goele Pipeleers (K.U.Leuven, Belgium)
Jan Swevers (K.U.Leuven, Belgium)

This paper presents a practical way to design gain-scheduled controllers for linear parameter varying (LPV) systems. An existing state-space model interpolation method for LPV systems is exploited in order to derive the desired controller. The interpolation requires designing local LTI controllers for local working conditions of the system, which is performed using a multi-objective $H_\infty$ approach. To simplify the weighting function design, the $H_\infty$ objective is broken apart into different $H_\infty$ design objectives and constraints, each related to various input-output combinations. The developed LPV control design approach is illustrated on an over-head crane system.

Subliminal Calibration for Machine Operation with Prediction based Filtering
Hiroshi Igarashi (Tokyo Denki University, Japan)

This paper addresses a skill assist technique without awareness. Generally, human assist system is by adding autonomous input to the operation command as force from obstacles. Although these assists are suitable in a particular task, they may bring about hindering human learning process. This paper focused on the human learning to utilize for suitable human-machine systems. The assist is carried out without human awareness, namely “subliminal”, and it does not hinder the operator’s learning ability. Further, since the technique is based on prediction of operator’s input command, subliminal filtering method is applied to improve its prediction accuracy. Then, in spite that the experimental results show the proposed technique make NOT the operators aware of, the operation performance is improved especially on low skilled operators.

Acceleration Control of Stacked Piezoelectric Actuator utilizing Disturbance Observer and Reaction Force Observer
Shinnosuke Yamaoka (Keio University, Japan)
Takahiro Nozaki (Keio University, Japan)
Daisuke Yashiro (Keio University, Japan)
Kouhei Ohnishi (Keio University, Japan)

Stacked piezoelectric actuators are suitable for micro manipulation since it has a high positional resolution and large generative force. However, it is difficult to control acceleration of piezoelectric actuator because of its hysteresis characteristic and spring characteristic. Therefore in this paper, piezo disturbance observer (PDOB) is proposed. Because PDOB treats hysteresis characteristic and spring characteristic as disturbance and compensates these elements, acceleration control is achieved. In addition, piezo reaction force observer (PRFOB) is proposed. By eliminating spring force from disturbance, PRFOB estimates the reaction force without utilizing any force sensors. Validities of PDOB and PRFOB are verified by experiments. Finally, experiment of micro-
Macro bilateral control (MMBC) constructed a master system and slave system is performed. The master system is a linear motor with conventional disturbance observer (DOB) and reaction force observer (RFOB). The slave system is a stacked piezoelectric actuator with PDOB and PRFOB. It achieved MMBC between a linear motor and a piezoelectric actuator.

**Sliding-Mode Control of a Flexure Based Mechanism Using Piezoelectric Actuators**

Merve Acer (Sabanci University, Turkey)
Asif Sabanovic (Sabanci University, Turkey)

The position control of designed 3 PRR flexure based mechanism is examined in this paper. The aim of the work is to eliminate the parasitic motions of the stage, misalignments of the actuators, errors of manufacturing and hysteresis of the system by having a redundant mechanism with a sliding mode control and a disturbance observer implemented. x-y motion of the end-effector is measured by using a laser position sensor and the necessary references for the piezoelectric actuators are calculated using the pseudo inverse of the transformation matrix coming from the experimentally determined kinematics of the mechanism. The effect of the observer and closed loop control is presented by comparing the results with open loop control. The system is designed to be redundant to enhance the position control. In order to see the effects of the redundant system firstly the closed loop control for active 2 piezoelectric actuators experiments then for active 3 piezoelectric actuators experiments are presented. As a result our redundant mechanism tracks the desired trajectory more accurately and its workspace is bigger.

**Design and Control of Laser Micromachining Workstation**

Edin Golubović (Sabanci University, Turkey)
Islam S.M. Khalil (Sabanci University, Turkey)
Ahmet Ö. Nergiz (Sabanci University, Turkey)
Eray A. Baran (Sabanci University, Turkey)
Asif Šabanović (Sabanci University, Turkey)

The production process of miniature devices and microsystems requires the utilization of nonconventional micromachining techniques. In the past few decades laser micromachining has became micromanufacturing technique of choice for many industrial and research applications. This paper discusses the design of motion control system for a laser micromachining workstation with particulars about automatic focusing and control of work platform used in the workstation. The automatic focusing is solved in a sliding mode optimization framework and preview controller is used to control the motion platform. Experimental results of both motion control and actual laser micromachining are presented.

**Circular Arc-Shaped Walking Trajectory Generation for Bipedal Humanoid Robots**

Metin Yilmaz (Sabanci University, Turkey)
Utku Seven (Sabanci University, Turkey)
Kaan Can Fidan (Sabanci University, Turkey)
Tunc Akbas (Sabanci University, Turkey)
Kemalettin Erbatur (Sabanci University, Turkey)

The design of a controller which can achieve a steady and stable walk is crucial in bipedal humanoid robotics. Reference trajectory generation is central in the walking control. The Zero Moment Point (ZMP) criterion is the most widely used stability criterion for trajectory generation. It is most successfully used when the ZMP equations are coupled with the dynamics equations of a simple mechanism, the Linear Inverted Pendulum Model (LIPM) which approximates the humanoid model. In a number of approaches the position reference for the Center of Mass (CoM) of the robot body is computed from pre-defined ZMP references. After the computation
of the CoM, the joint references are computed by inverse kinematics. A natural ZMP reference trajectory and a Fourier series approximation based method for computing the CoM reference from it, was previously proposed for the humanoid robot SURALP (Sabanci University Robotics ReseArch Laboratory Platform), for a straight walk. This paper improves these techniques by modifying the straight walk reference trajectory into an arc-shaped one. In principle the straight walk is projected into a walk reference on an arc with a desired radius. On-line smooth change of the walking direction is achieved by adjusting the arc radius command. The proposed reference generation algorithm is tested on SURALP. Experiments indicate that the method is successful in generating a stable walk following an arc.

**Gyroscope Integrated Environmental Mode Compliance Control for Biped Robot**

Takahiko Sato (Keio University, Japan)  
Hisashi Ono (Keio University, Japan)  
Kouhei Ohnishi (Keio University, Japan)

Many researchers proposed methods to adapt uneven terrain for biped robots. Environmental mode compliance control is one of those methods. Another feature of this control is that it makes a walking stability. However, the environmental mode compliance controller cannot maintain the body horizontally, and cannot be applied if the body is inclined. In this paper, gyroscope integrated environmental mode compliance control is proposed. This method can compensate the ZMP error due to the inclination of the body. Thus, this method can be applied even if the body is inclined. The validity of the proposed method is confirmed by experimental results.

**A Robotic Walker for Standing Assistance with Realtime Estimation of a Patient’s Load**

Daisuke Chugo (Kwansei Gakuin University, Japan)  
Yusuke Morita (Kwansei Gakuin University, Japan)  
Yuki Sakaida (RIKEN, Japan)  
Sho Yokota (Setsunan University, Japan)  
Kunikatsu Takase (The University of Electro-Communications, Japan)

This paper proposes a standing assistance control for our robotic walker system. Our developing assistance system is based on a walker which is a popular assistance device for an aged person in normal daily life and realizes a standing motion using its support pad which is actuated by novel assistance manipulator mechanisms with four parallel linkages. Our system assists a standing motion using a remaining physical strength of a patient maximally in order not to decrease a force generating capacity of the patient. For realizing this function, this paper proposes the following two topics. The first topic is an estimation scheme of a patient’s load. During standing assistance, our system measures the body motion and the applied force of a patient, and our system estimates the load of pelvis, knee and ankle joint using a linkage model which approximates the human body. The second topic is a combination of force and position control. According to the estimated load of a patient during standing motion, our control system selects more appropriate control method from them and realizes the standing assistance using the physical strength of the patient. The performance of our system is verified by experiments using our prototype.

**High Mobility Control for Wheel-Legged Mobile Robot Based on Resolved Momentum Control**

Akihiro Suzumura (Yokohama National University; Japan)  
Yasutaka Fujimoto (Yokohama National University; Japan)

This paper deals with realization of both rapidity and stabilities for four wheel-legged locomotion. To achieve these aims, two control approaches are proposed. First, we show the kinematic modeling of constraint for wheel-legged mechanism to achieve the three-dimensional locomotion. Then, the proposed constraint is applied to the Resolved Momentum Control. This method realizes the dynamic locomotion by considering the Center of Mass and angular momentum directly affecting the stability of dynamic locomotion. Second, a trajectory generating method by using Zero-Phase Low Pass Filter based on a cart-table model is applied. These schemes can control the robot by stabilizing the Zero Moment Point which is the criteria of dynamic locomotion. In this paper, we
focus on the realization of fast and stable wheeled locomotion. Finally, the effect of proposed methods is confirmed by simulations and experiments.

**Robot motion planning considering the utterance-timing and its experimental evaluation**

Satoshi Suzuki (Tokyo Denki University, Japan)
Jun Goto (Tokyo Denki University, Japan)
Hiroyuki Igarashi (Tokyo Denki University, Japan)
Harumi Kobayashi (Tokyo Denki University, Japan)
Tetsuya Yasuda (Tokyo Denki University, Japan)
Fumio Harashima (Tokyo Metropolitan University, Japan)

For a natural communication robot cooperating with human, an adequate control mechanism of motion and utterance is required. This paper presents a robot motion planning method which considers an utterance timing using Self-Organizing Map (SOM). Adequate target position of the robot motion and an utterance timing for an autonomous robot is decided by searching the best-matching-node at the SOM which was trained using normative human behavior. Applying the presented method to cooperative carrying situation in a virtual cooperative simulator, human impression to the robot behavior was investigated. As a result, it was confirmed by the Tukey-Kramer test that several human recognized the effect of the utterance timing and motion planning method.

**BC-2 Bilateral Control II**

**Coding and Decoding Scheme for Wide-band Bilateral Teleoperation**

Mariko Mizuochi (Hitachi, Ltd, Japan)
Kouhei Ohnishi (Keio University, Japan)

Precise bilateral teleoperation based on wide-band signals enables an operator to achieve complicated tasks. A short sampling period is required for acquisition and transmission of wide-band signals. The sampling period is limited, however, when controllers are connected through a network. In this paper, a coding and decoding scheme for wide-band bilateral teleoperation is proposed. The method uses a low pass filter and discrete Fourier transform for the coding and inverse discrete Fourier transform for the decoding. High frequency signals can be transmitted even under severe limitation on the packet transmission rate. The scheme was verified through experiment with bilateral teleoperation. The validity of the proposed method was confirmed in terms of the transmission of wide-band signals and the reproduction of wide-band haptic sensation.

**Data Transmission with Multiple-Routes for Wireless Haptic Communication System**

Nozomi Suzuki (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

Recently, the teleoperation robot which transmits tactile sensation has actively been researched following visual and audio information. For the realization of haptic transmission, a master and slave system is utilized and these systems have to be connected via network in actual applications. In communication via network, it is known that a communication delay, packet loss and jitter are undesirable effects on control system occur. Moreover, large burst loss may also occur in wireless mobile communication by changing access points for the expansion of the range of communication. In order to realize vivid haptic transmission through network, hard realtime property and transfer reliability are demanded. There are many conventional studies which focus on communication delay, on the other hand, studies about the reliability of data transfer on haptic communication are not conducted so much. Therefore, this study pays attention to the burst loss by hand over in wireless haptic communication. To tackle this problem, this paper proposes new haptic transmission method which
uses multiple-routes. By using the method, the effect of the burst loss is decreased in communication with the single route. The viability of the proposal is shown by two kinds of experimental results of bilateral control. The one is stationary system, and the other one is mobile system. As for the experiment of the mobile system, this study uses the newly-developed mobile-hapto.

**Positive Feedback of Reaction Force for Environmental Embedded Haptic System**
Hiroyuki Nagai (Keio University, Japan)
Seiichiro Katsura (Keio University, Japan)

Technology and science have been developing rapidly, and robotic system for human support has been researched recently. Considering the effect of low birthrate and longevity, the system is thought to become important in the future. In this research, environmental embedded haptic system for human support is developed. In order to realize the haptic system, impedance control with positive feedback is proposed. In this research, the stability analysis of the system is mainly focused on, and it is conducted by displacement poles. The validity of the proposed method is shown by simulation and experimental results.

**Novel Fuzzy — Smith predictor hybrid scheme for periodic disturbance reduction in linear time delay systems**
Ahmet Kuzu (Tubitak-Bilgem-Bte, Turkey)
Ozgur Songuler (Tubitak-Bilgem-Bte, Turkey)

In this study, a modified Smith Predictor based fuzzy disturbance rejection scheme is proposed for short delay processes, and compared with a recent counterpart. For this purpose, Astrom’s Smith Predictor and the grey predictor are introduced, a recent disturbance reduction scheme and proposed disturbance reduction scheme are described, and both are simulated with pre-published process parameters. The simulation results are compared, and it has been concluded that the disturbance reduction performance is improved by using proposed scheme.

**Predictive Input Delay Compensation for Motion Control Systems**
Eray A. Baran (Sabanci University, Turkey)
Asif Šabanović (Sabanci University, Turkey)

This paper presents an analytical approach for the prediction of future motion to be used in input delay compensation of time-delayed motion control systems. The method makes use of the current and previous input values given to a nominally behaving system in order to realize the prediction of the future motion of that system. The generation of the future input is made through an integration which is realized in discrete time setting. Once the future input signal is created, it is used as the reference input of the remote system to enforce an input time delayed system, conduct a delay-free motion. Following the theoretical formulation, the proposed method is tested in experiments and the validity of the approach is verified.

**Low-Noise and Fine-Efficiency Motor Drive for Motion Control**
Yuki Yokokura (Nagaoka University of Technology, Japan)
Kiyoshi Ohishi (Nagaoka University of Technology, Japan)
Seiichiro Katsura (Keio University, Japan)

In this paper, Class-G power amplifiers for motion control are developed. General Class-B power amplifier cannot be used for driving high-power actuators because of power efficiency. On the other hand, due to PWM, typical Class-D power amplifier generates switching noise as well as desired current. The switching noise caused by PWM inverter degrades the control performance of the motor. In short, typical Class-B and Class-D power amplifiers are not suitable for advanced motion control. By using Class-G amplifier, problem of both power efficiency and noise is able to be solved. Therefore, Class-G amplifier enhances the control performance of current controller for motion control. Driving test of Class-G power amplifiers is conducted. The current controller and force control system are implemented in FPGA. By the experiments, validity of the current control and force control with Class-G power amplifier is verified.
### Four-wheel Driving-force Distribution Method for Instantaneous or Split Slippery Roads for Electric Vehicle with In-wheel Motors

Kenta Maeda (University of Tokyo, Japan)
Hiroshi Fujimoto (University of Tokyo, Japan)
Yoichi Hori (University of Tokyo, Japan)

In this paper, a four-wheel driving force distribution method based on driving force control is proposed. Driving force control is a traction control method, previously proposed by the authors' research group, which generates appropriate driving force based on the acceleration pedal. However, this control method can not completely prevent reduction of driving force when a vehicle runs on an extremely slippery road. If the length of a slippery surface is shorter than the vehicle's wheel base, the total driving force is retained by distributing the shortage of driving force to the wheels that still have traction. On the other hand, when either the left or right side runs on a slippery surface, yaw-rate is suppressed by reducing the driving force of the opposite side. Therefore, four-wheel driving force distribution method is proposed for retaining driving force on instantaneous slippery roads, and suppressing yaw-rate on split ones. The effectiveness of the proposed distribution method is verified by experiments.

### Terrace Climbing of the Alacrane Mobile Robot with Cooperation of its Onboard Arm

Javier Serón (University of Malaga, Spain)
Jorge L. Martinez (University of Malaga, Spain)
Anthony Mandow (University of Malaga, Spain)
Alfonso García-Cerezo (University of Malaga, Spain)
Jesus Morales (University of Malaga, Spain)
Antonio Reina (University of Malaga, Spain)
Jesus García (Universidad Nacional experimental del Tachira, Venezuela)

Alacrane is a hydraulic mobile manipulator for search and rescue in disaster areas and natural environments, where surmounting elevations such as rubble mounds and terraces is usually required. The paper describes the autonomous terrace climbing maneuver of this mobile robot with the help of its powerful arm. During this operation, the arm is used both for levering, by pushing against the ground, and for modifying the center of gravity of the entire robot. A 3D laser scanner, an IMU and joint absolute encoders provide all the sensorial information required for this maneuver. Furthermore, a fast method is proposed to estimate the relative pose and height of the terrace slope from a 3D scan. Experimental results in an outdoor environment are presented to demonstrate the utility of the proposed approach.

### Modified Histogramic Technique for Mobile Robot Indoor Environment Mapping Based on Uniform Random Distribution

Dinko Osmanković (ETF University of Sarajevo, BiH)
Jasmin Velagić (ETF University of Sarajevo, BiH)

In this paper we introduce a modification of histogramic in-motion mapping technique for mobile robots. This modification is based on the premise that precise sonar model is not required for accurate map building. We use uniform random distribution approach to replace the probabilistic model of sonar sensor. Problem of localization of the mobile robot is also discussed as it is very important for the precise mapping of the environment. For this purpose we used odometry measurements processed by Extended Kalman Filter for the robot localization. It is shown that this method gives precise maps of an environment in Player/Stage simulator, and also with real world scenarios.
# Coefficient of Agility and Sampling Frequency issues in Mobile Agents Collision Detection with Dynamic Obstacles in 3D Space

Elmir Babović (FIT Mostar, BiH)

This research is extension of previous research on method of Collaborative and Non-Collaborative Dynamic Path Prediction Algorithm for Mobile Agents Collision Detection with Dynamic Obstacles in 3D Space. In this research the extension of the algorithm for dynamic collaborative path prediction for mobile agents is proposed and two important issues Coefficient of agility and Minimal sampling frequency are analyzed. Those two terms are proposed in previous research for which background and introduction is explained in this paper. Solving Coefficient of agility and minimal sampling frequency issues allows system designers and developers to implement the method. This method allows full decentralization of collision detection which allows many advantages from minimizing of network traffic to simplifying of inclusion of additional agents in relevant space. Implementation of the algorithm will be low resource consuming allowing mobile agents to free resources for additional tasks.

# Zero Moment Point Based Pace Reference Generation for Quadruped Robots via Preview Control

Tunc Akbas (Sabanci University, Turkey)
Sefik Emre Eskimez (Sabanci University, Turkey)
Selim Ozel (Sabanci University, Turkey)
Omer Kemal Adak (Sabanci University, Turkey)
Kaan C. Fidan (Sabanci University, Turkey)
Kemalettin Erbatur (Sabanci University, Turkey)

Legged robots have significant advantages over other types of mobile robots when task at hand requires the robot to overcome obstacles. This paper presents a reference trajectory generation method for a quadruped robot for pace gait on a flat surface. The approach is based on the Zero Moment Point (ZMP) stability criterion and the Linear Inverted Pendulum Model (LIPM). ZMP reference trajectories for pace is proposed, from which reference trajectories for the Robot Center of Mass (CoM) references are obtained by applying preview control. The position of leg joints are computed using inverse kinematics according to CoM reference trajectory. Proposed reference trajectory generation synthesis is tested through full-dynamics 3- D simulation. A 16-degrees-of-freedom (DOF) quadruped robot model is used in the simulations. Simulation results show the success of the reference generation technique for the pace gait.
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