

# 2019 IEEE International Conference on Mechatronics and Automation

August 4-7, 2019 Tianjin, China



[Welcome Message](#)  
[Conference Information](#)

[Author Index](#)

[Program at a Glance](#)  
[Table of the Contents](#)



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# **2019 IEEE International Conference on Mechatronics and Automation**

**August 4 - 7, 2019  
Tianjin, China**

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# Foreword

On behalf of the IEEE ICMA 2019 Conference Organizing Committee, it is our great pleasure, an honor, and a privilege to welcome you to Tianjin for the 2019 IEEE International Conference on Mechatronics and Automation. This conference reflects the growing interests in the broad research areas of mechatronics, robotics, sensors and automation.

ICMA 2019 marks the 16<sup>th</sup> edition of the IEEE ICMA annual conference series. We are proud to announce that a high number of **682** papers were submitted from **28** countries and regions, including **658** contributed papers, **24** papers for organized sessions, and **449** papers were accepted for oral or poster presentation at the conference after a rigorous full-paper review process, achieving an acceptance rate of less than **66%**. Presentations at ICMA 2019 are organized in 7 parallel tracks, for a total of **61** sessions, including **1** poster session, taking place during the three conference days. We are fortunate to be able to invite four distinguished speakers to deliver Keynote Speech and plenary talks.

We are very glad that you are joining us at IEEE ICMA 2019 in Tianjin to live this unique experience. The main objective of IEEE ICMA 2019 is to provide a forum for researchers, educators, engineers, and government officials involved in the general areas of mechatronics, robotics, sensors and automation to disseminate their latest research results and exchange views on the future research directions of the related fields. IEEE ICMA 2019 promises to be a great experience for participants from all over the world, with an excellent technical program as well as social activities.

We would like to express our most sincere appreciation and thanks to all of our sponsoring societies and organizations and to all the individuals who have contributed to the organization of this conference. Our special thanks are extended to our colleagues in the Program Committee for their thorough review of all the submitted papers, which is vital to the success of this conference. We must also extend our thanks to our Organizing Committee and our volunteers who have dedicated their time toward ensuring the success of this conference. Last but not least, we thank all the contributors for their support and participation in making this conference a great success. Finally, we wish you a great conference and enjoyable stay in Tianjin, China.



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**Optics and Precision Engineering**



# General Information

## Tianjin

Tianjin is one of China's four municipalities under the direct administration of central government. It is an international port city and the largest seaside city in the North of China, 137 km away from Beijing, the capital of China. Tianjin is a birthplace of modern industry of China: the first wrist watch, bicycle and television in New China were all made here. Since 1980s, Tianjin has turned itself into an important industrial base in North China. Tianjin is also a transportation hub with railway, waterway, highway and airway connecting other major cities in China and outside the country.

The name of Tianjin, which means “Emperor's port”, was adopted in the first year of Yongle Reign in Ming Dynasty. In the second year of Yongle Reign(1404), Tianjin became a walled garrison and began to be known as “Tianjin Wei”. In 1860 Tianjin was opened as a trading port. In the 1930s, it became the largest industrial and commercial city and financial center in the north of China. After the founding of the People's Republic of China in 1949, Tianjin became a municipality directly under the central government. After China adopted the policy of reform and opening up in 1978, Tianjin became one of the first coastal cities that are open to the outside world. Today, the city function according to the central government has been designated as becoming an international harbor city, economic center in north China, and an ecological city.

As one of the first cities open to the outside world, Tianjin has an excellent environment for business and investment. Up till now, among the top 500 world leading enterprises, more than 120 have invested in Tianjin. With the involvement of Binhai New Area in the national development strategy, Tianjin has become an area with the greatest attraction for investors and the highest investment profit rates in China.

Tianjin is a well known city with a long history and abundant resources. Panshan Mountain, the No. 1 Mountain in Capital's East; Dule Temple, one of the oldest wooden structures in China; Ancient Culture Street, full of ancient Chinese culture and Tianjin custom. More surprises are waiting for your exploration.

## Attractions

### ➤ Dule Temple

Dule Temple is a Buddhist temple located in the town of Jixian, in Ji County, under the administration of the city of Tianjin, China. The temple is of historical as well as architectural significance. Its oldest surviving buildings are two timber-frame structures, the front gate and the central hall that houses a colossal clay statue of the goddess Guanyin. Both structures date back to the Liao Dynasty and are among the oldest surviving wooden buildings in China.



### ➤ Shi Family Grand Courtyard



Shi Family Grand Courtyard is situated in Yangliuqing Town of Xiqing District, which is the former residence of wealthy merchant Shi Yuanshi – the 4th son of Shi Wancheng, one of the eight great masters in Tianjin. First built in 1875, it covers over 6,000 square meters, including large and small yards and over 200 folk houses, a theater and over 275 rooms that served as apartments and places of business and worship for this powerful family. Shifu Garden, which finished its expansion in October 2003, covers 1,200 square meters, incorporates the elegance of imperial garden and delicacy of south garden. Now the courtyard of Shi family covers about 10,000 square meters, which is called the first mansion in North China. Now it serves as the folk custom museum in Yangliuqing, which has a large collection of folk art pieces like Yanliuqing New Year pictures, brick sculpture.

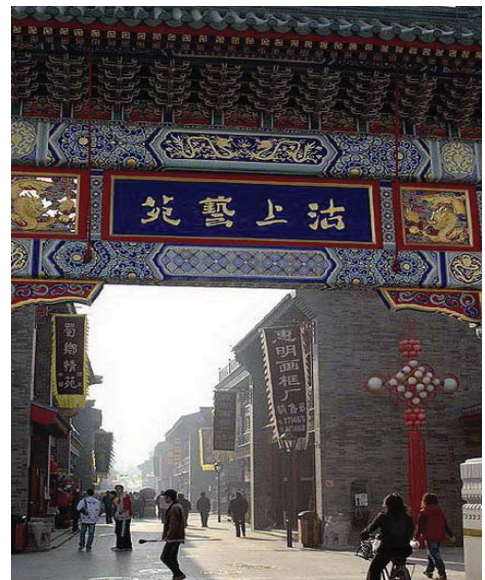
Shi's ancestor came from Dong'e County in Shandong Province, engaged in water transport of grain. As the wealth gradually accumulated, the Shi Family moved to Yangliuqing and bought large tracts of land and set up their residence. Shi Yuanshi came from the fourth generation of the family, who was a successful businessman and a good household manager, and the residence was thus enlarged for several times until it acquired the present scale. It is believed to be the first mansion in the west of Tianjin.

Today, the Shi mansion, located in the township of Yangliuqing to the west of central Tianjin, stands as a surprisingly well-preserved monument to China's pre-revolution mercantile spirit. It also serves as an on-location shoot for many of China's popular historical dramas. Many of the rooms feature period furniture, paintings and calligraphy, and the extensive Shifu Garden.

### ➤ **Ancient Cultural Street**

Tianjin Ancient Culture Street with 600 years history, standing in the area of key section in upstream of the Haihe River, is located in Nankai district of Tianjin. Covering an area of 224,200 sq meters, it used to be one of earliest water transport docklands in Tianjin where is one of the busiest cities of commerce and trade in history. As a cultural precinct, Tianjin Ancient Culture Street is well known by the local and overseas tourists. The two attractions, Yuan Huang Ge and Tian Hou Temple are two historic cultural relics in the list of city level ones reversed.

Tianjin Ancient Cultural Street rebuilt in 1980's is one of the great successes in the renovation and redevelopment. The whole block is still conserved the existing urban pattern and tissue of traditional Chinese layout. The lanes and houses in the Street are almost preserved in a good condition with Tianjin local features. In past time, whenever the day of 23th of March in lunar calendar was coming, a great ceremony would be held here, which it is said that it is the birthday of heaven Mother.



### ➤ **Goubuli**

Goubuli, also sometimes translated as Go Believe, is a brand of stuffed baozi from Tianjin, China. Founded in 1858, it is one of China's longest established brands. Each Goubuli bun has eighteen wrinkles. There are many explanations for the name Goubuli. The oft-quoted one relates to a poor village boy nicknamed Gouzhai. At 14, he became an apprentice at a food store. Thereafter, he set up his own shop specialising in selling steamed, stuffed baozi. His supposedly very delicious baozi soon gained immense popularity in a short period of time. As a result, Gouzhai got too occupied with his business to converse with his customers. So, they started to complain, "Gouzhai does not talk to people".



# Weather

Tianjin features a four season, monsoon-influenced climate, typical of East Asia, with cold, windy, very dry winters reflecting the influence of the vast Siberian anticyclone, and hot, humid summers, due to the monsoon.

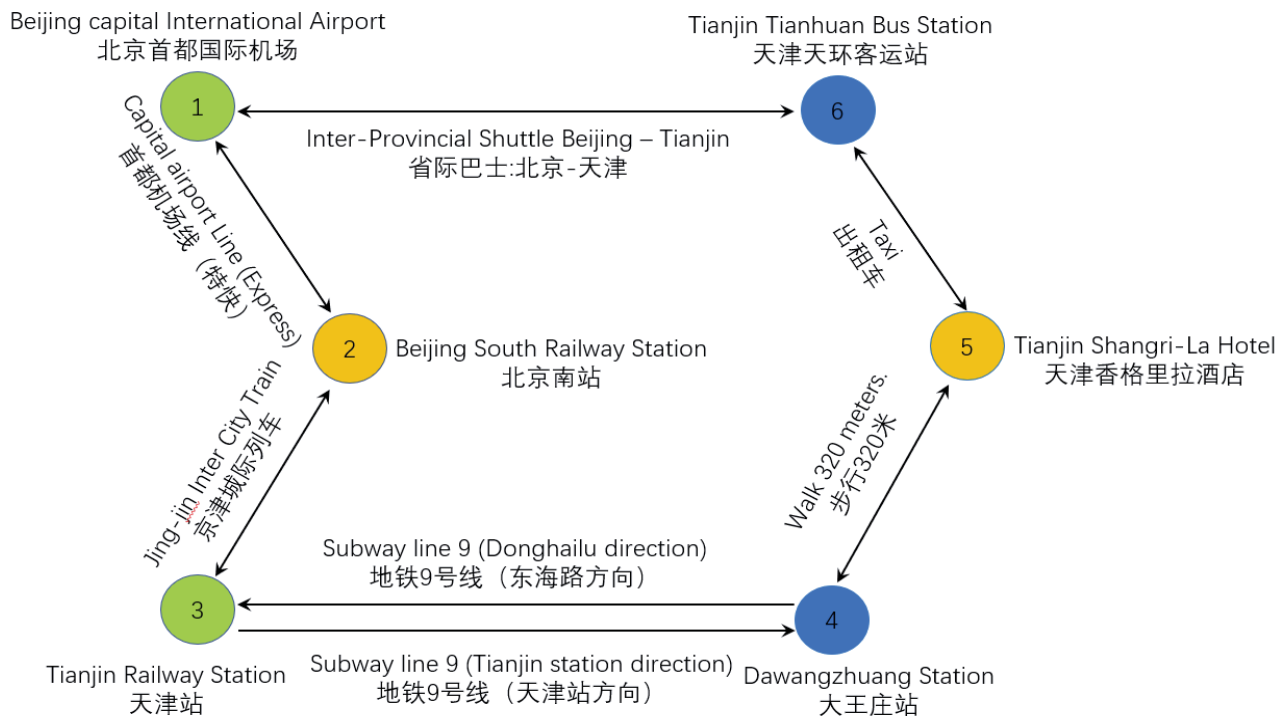
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
° F	26.8	23.2	43.7	68.9	79.0	86.2	87.8	86.4	79.3	67.5	51.1	39.0
° C	-2.8	-4.9	6.5	20.5	26.1	30.1	31.0	30.2	26.3	19.7	10.6	3.9

# Transportation

All the registrants should make their own local transportation in the city. Travel by taxi is the most convenient and faster option for the journey. Tianjin is not only famous for charming natural scenery but also for large numbers of taxis and cheapest taxis cost: RMB 2.00 per km with base price RMB 8.00 ! Please prepare some changes in advance for taxi fee or subway in the staying in Tianjin. We suggest you wait for taxi at the airport designated taxi station. Please ask for a receipt with the taxi.

## Transportations from/to Airport

### ➤ Transportations from/to Beijing Capital International Airport



**Route 1:** Traffic information about the Beijing Capital International Airport (北京首都国际机场) – Tianjin Shangri-La Hotel (天津香格里拉酒店) (1→2→3→4→5)

**1st Step:** Between Beijing Capital International Airport (北京首都国际机场) and Beijing South Railway Station (北京南站), you can take Capital Airport Line (Express) (机场线) or Taxi.

**PS 1:** If you take Capital Airport Line (Express) (机场线) for Beijing South Railway Station (北京南站), You will need to change Line 2 (2 号线) at Dongzhi Men (东直门) and then change Line 4 (4 号线) at Xizhi Men (西直门). From Beijing South Railway Station (北京南站) to Beijing Capital International Airport (北京首都国际机场), you can take Line 4 (4 号线) and then change Line 2 (2 号线) at Xizhi Men (西直门), next change Capital Airport Line (机场线) at Dongzhi Men (东直门). The one-way fee is about 30 RMB.

**PS 2:** If you take taxi, the distance is about 37.2 km and you need to pay about 120 RMB.

**2nd Step:** Between Beijing South Railway Station (北京南站) and Tianjin Railway Station (天津站), please take Jing-jin Inter city Train (京津城际列车).

**PS:** The train runs from AM 6:13 to PM 10:56 with interval of 20 minutes every day and the one-way time is about 33 minutes. The fee is about 66 RMB.

**3rd Step:** Between Tianjin Railway Station (天津站) and Tianjin Shangri-La Hotel (天津香格里拉酒店), you can take Subway line 9 or Taxi.

**PS 1:** If you take taxi, the distance is about 2.4 km and you need to pay about 9 RMB.

**PS 2:** If you take Subway line 9, from/to Tianjin Railway Station (天津站) to/from Dawangzhuang Ave station (大王庄站), you need to pay about 2 RMB and you can take the Exit C. You can walk to Tianjin Shangri-La Hotel (天津香格里拉酒店) with 320m.

**Route 2:** Traffic information about the Beijing Capital International Airport (北京首都国际机场) – Tianjin Shangri-La Hotel (天津香格里拉酒店) (1→6→5)

**1st Step:** From/to Beijing Capital International Airport (北京首都国际机场), you can take Inter-Provincial Shuttle Beijing – Tianjin (省际巴士:北京-天津) to/from Tianjin Tianhuan Bus Station (天津天环客运站) which will take 2 hours and a half and 82 RMB.

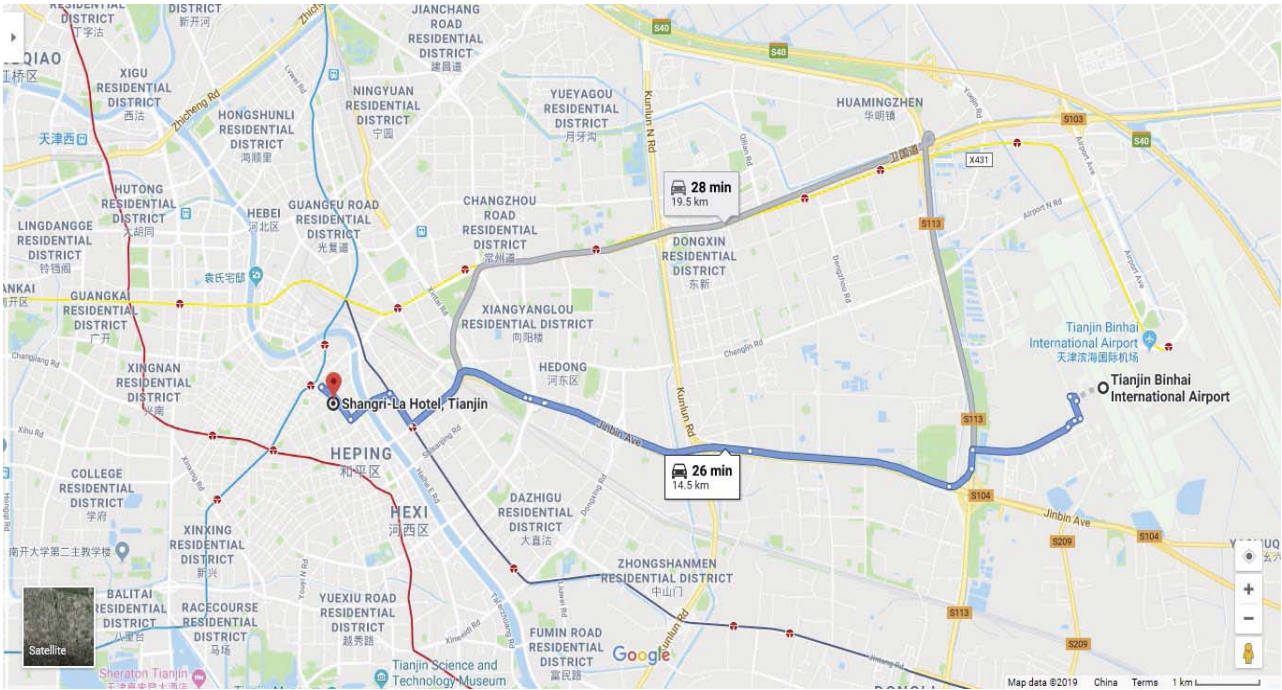
**PS 1:** Beijing departure point: T1/T2: In front of Gate 15 on the 1st Floor of T2; T3: In front of Gate 1 on the 1st Floor, departure time is from 8:00 to 23:00 with about 1 hour interval.

**PS 2:** Tianjin departure point : Starting from the northeast corner of the crossing of Hongqi Rd (红旗路) and Anshan West Avenue (鞍山西道), Tianjin departure time is from 4:00 to 18:00 with about 1 hour interval.

**2nd Step:** Between Tianjin Tianhuan Bus Station (天津天环客运站) with Tianjin Shangri-La Hotel (天津香格里拉酒店), you can take taxi with about 19 RMB and 30 minutes.

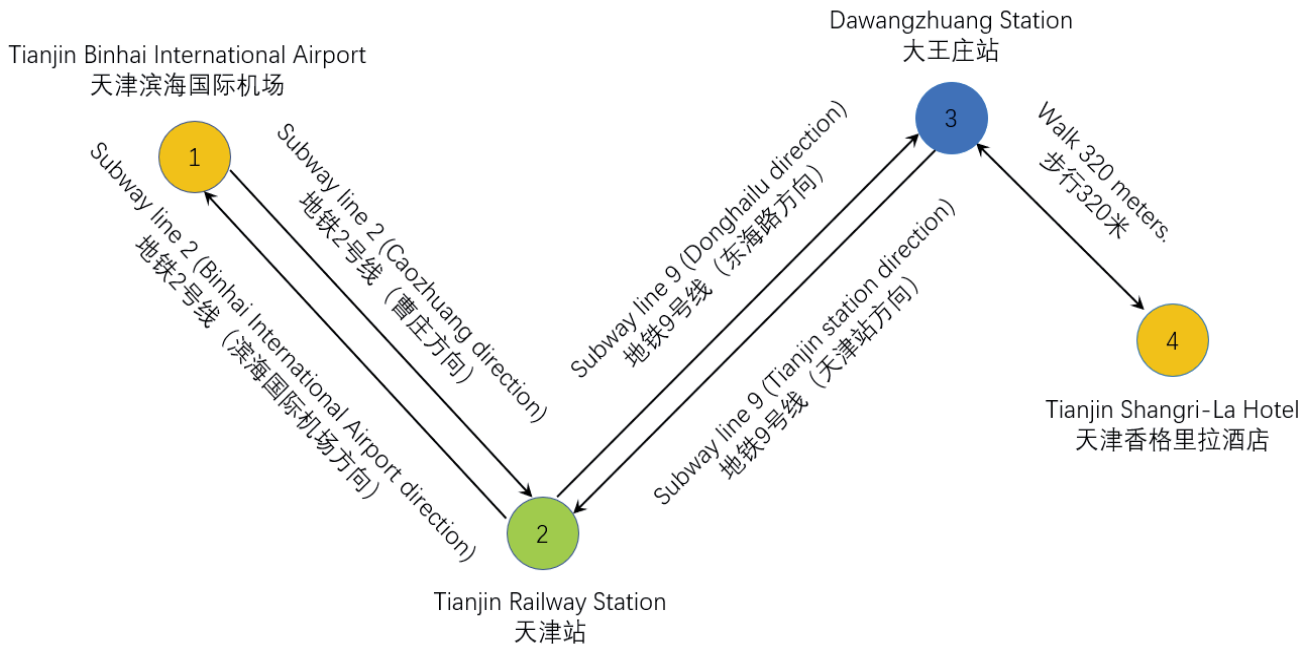


➤ Transportations from/to Tianjin Binhai International Airport by taxi



PS: It will take about 26 minutes. The distance is about 14.5 km and you need to pay about RMB 42 Yuan.

➤ Transportations from/to Tianjin Binhai International Airport by Bus

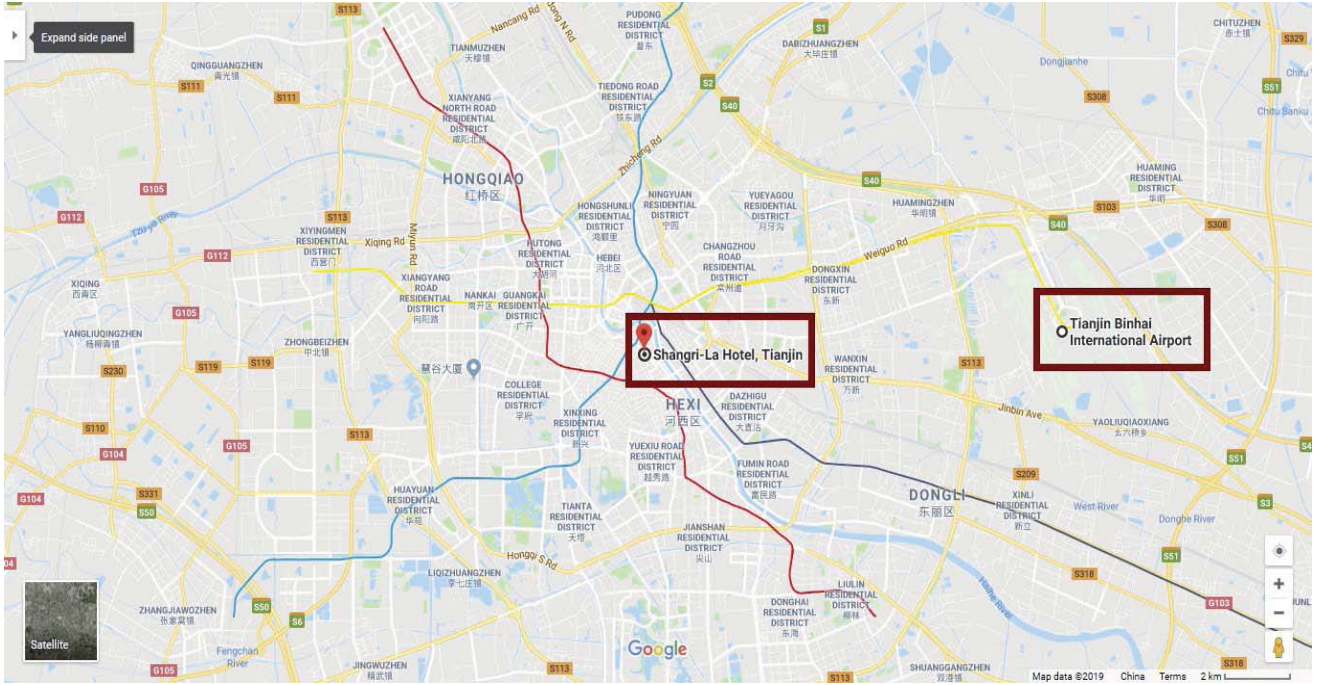


**Route:** Tianjin Binhai International Airport (天津滨海国际机场) – Tianjin Shangri-La Hotel (天津香格里拉酒店) (1→4)

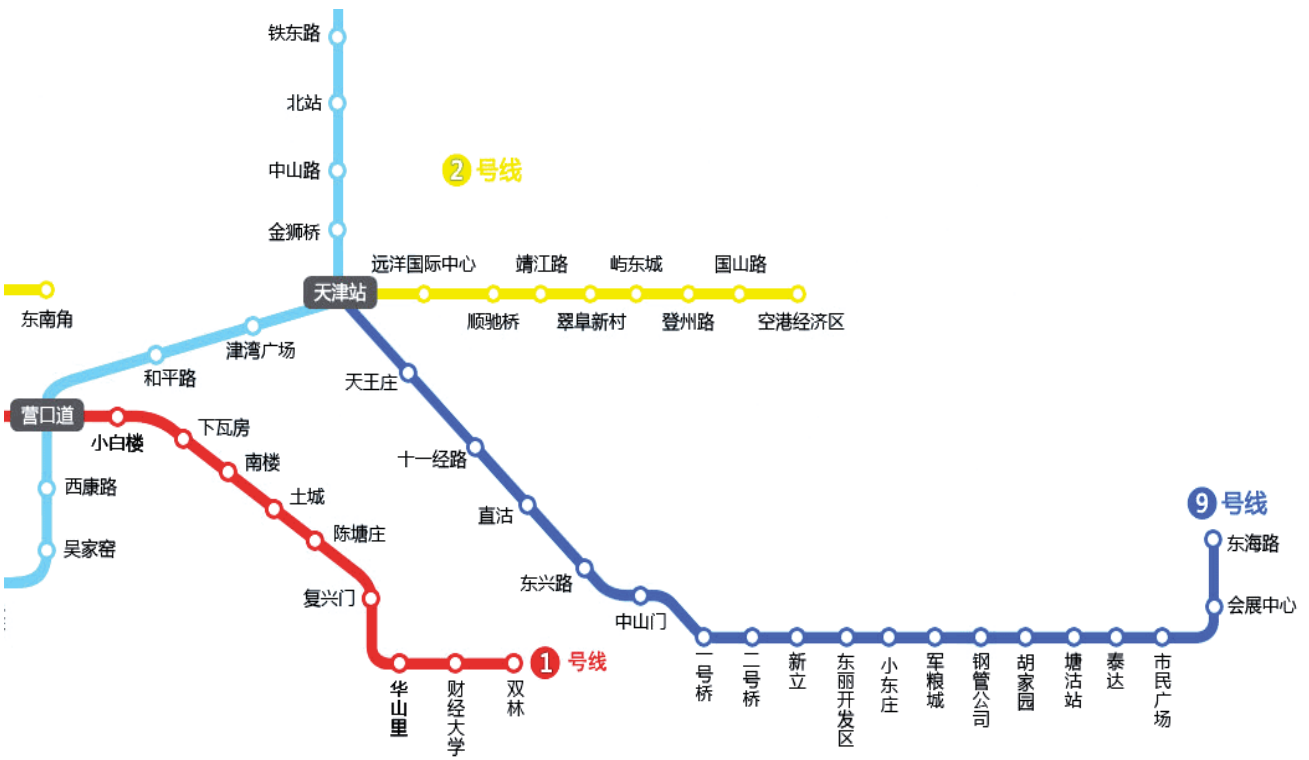
PS : It will take about 43 minutes. The distance is about 17.2 km and you need to pay about RMB 6 Yuan.

# Appendix:

## ➤ The position of Tianjin Shangri-La Hotel



## ➤ Part of Tianjin Metro



## Useful Information

- **Language:** Official language is Mandarin and most people also use their local dialect. The native language in Tianjin is Tianjinese. The standard spoken Chinese is Putonghua. English can be understood by many young people and is used in hotels and big restaurants. In all tourist hotels, staff can speak in English, Japanese and other languages. They can also write down addresses or instructions in Chinese for taxi drivers or others. In addition, roads in major cities are signposted in Pinyin, the official Romanization system of the Chinese characters, which makes it quite easy to get around with the help of a map.
- **Currency:** Renminbi (RMB) is the only currency to be used in China. RMB is also called Chinese Yuan. The unit of Renminbi is yuan and with smaller denominations called jiao. The conversion among the two is : 1 yuan =10 jiao. Paper notes are issued in denominations of 1, 5, 10, 20, 50 and 100 yuan. Coins are issued in denominations of 1 yuan; 5 jiao; 1 jiao.

Money exchanges by cash or travel's cheques can be made at the branches of Bank of China at Tianjin Binhai International Airport, hotels and tourist stores. Please remember to keep the receipt to exchange back to foreign currency when leaving China.

- **Credit Cards:** Visa, Master Card and American Express are the most commonly used in China. Cards can be used in most middle to top-range hotels, department stores, but they cannot be used to finance your transportation costs.
- **Time:** GMT + 8 hours (the whole of China is set to Beijing time)
- **Electricity:** Electricity is 220 Volts, 50 AC; plugs can be three-pronged angled, three-pronged round, two flat pins or two narrow round pins.
- **Water:** Bottled mineral water can easily be bought in all stores and street kiosks for RMB 3. And sometimes hotels provide it free of charge. Furthermore, potable water is only available in a few 4 to 5 star hotels, while water in thermos flasks in rooms is usually non-potable tap water.
- **Measurement:** In Metric system
- **Tipping:** Tipping is not customary outside of the foreign joint-venture hotels and is officially discouraged. But hotel bellboys usually expect RMB 2-5 per bag.
- **Attention:** Smoking is prohibited in public places in Tianjin, such as hospitals, office buildings, theatres, cinemas, museums, planes, and trains.
- **Hotlines:** 110 - Police    119 – Fire    120 – Ambulance



# Conference Information

## Conference Venue

IEEE ICMA 2019 will be held in the city of Tianjin, at Shangri-La Hotel. Tianjin Shangri-La Hotel located within the fully-integrated Tianjin Kerry Centre, connected to the Riverview Place shopping mall, luxurious residences, and an array of dining and entertainment options. Take the subway to Dawangzhuang Station on line 9 and exit from entrance C or D, which are located in the Riverview Place shopping mall. The hotel is 25-minute drive from Tianjin Binhai International Airport, 5 minutes to Tianjin Railway Station by car and 2 hours' drive from Beijing.



## Chinese Address Cards

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**Tianjin Shangri-La Hotel**

天津香格里拉酒店

地址：中国天津市河东区海河东路 328 号

Tel : 86-22-8418-8888

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## Conference Registration

A conference registration desk will be set up and opened at the FUNCTION ROOM of 1st Floor of Tianjin Shangri-La Hotel from August 4 (13:30) to August 7 (11:00) as followings.

August 4, 2019	13:30~18:30 (near the escalator of 1st Floor)
August 5, 2019	07:30~12:00 (near the escalator of 1st Floor)
August 5, 2019	12:00~18:30 (near Room 6 of 1st Floor)
August 6, 2019	08:00~18:00 (near Room 6 of 1st Floor)
August 7, 2019	08:00~11:00 (near Room 6 of 1st Floor)

## Internet Access

Free internet access will be provided during the conference period, to the IEEE ICMA 2019 participants at the Conference Room on 1st floor and 2nd floor of Tianjin Shangri-La Hotel (天津香格里拉酒店). Broadband internet access services are also provided at the conference hotel for a fee. For the fee information, please contact the hotel you are staying directly.

# Social Events

The social events organized by the IEEE ICMA 2019 include the conference reception, the awards banquet, the conference registration, the farewell party, etc.

## Conference Reception

The Conference Reception will be held from 17:30 to 18:30 on August 4, 2019 in Conference Room 4 (DIAMOND 2), 1F of Tianjin Shangri-La Hotel (天津香格里拉酒店). All the conference participants are welcome to join this event.

## Awards Banquet

The Awards Banquet will be held from 18:30 to 21:00 on August 6, 2019 in Conference GRAND BALLROOM (BALLROOM 2), 2F of Tianjin Shangri-La Hotel (天津香格里拉酒店). All the conference participants are welcome to join this event.

## Farewell Party

The Farewell Party will be held from 12:00 to 13:00 on August 7, 2019 in Conference Room 4 (DIAMOND 2), 1F of Tianjin Shangri-La Hotel (天津香格里拉酒店). All the conference participants are welcome to join this event.

# IEEE ICMA 2019 Conference

## Plenary Talk 1

### CPS Driven Control System

### Tianyou Chai, Ph.D.

Director of National Research Center for Metallurgical Automation Technology,  
Professor

Department of Automatic Control

Northeastern University, P.R. China



#### ***Abstract:***

China has abundance of mineral resources such as magnesite, hematite and bauxite, which constitute a key component of its economy. The relatively low grade, and the widely varying and complex compositions of the raw extracts, however, pose difficult processing challenges including specialized equipment with excessive energy demands. The energy intensive furnaces together with widely uncertain features of the extracts form hybrid complexities of the system, where the existing modeling, optimization and control methods have met only limited success. Currently, the mineral processing plants generally employ manual control and are known to impose greater demands on the energy, while yielding unreasonable waste and poor operational efficiency. The recently developed Cyber-Physical

System (CPS) provides a new key for us to address these challenges. The idea is to make the control system of energy intensive equipment into a CPS, which will lead to a CPS driven control system. This talk presents the syntheses and implementation of a CPS driven control system for energy-intensive equipment under the framework of CPS. The proposed CPS driven control system consists of four main functions: (I) setpoint control; (II) tracking control; (III) self-optimized tuning; and (IV) remote and mobile monitoring for operating condition. The key in realizing the above functions is the integrated optimal operational control methods to implement setpoint control, tracking control and self-optimized tuning together seamlessly. This talk introduces the integrated optimal operational control methods we proposed.

Hardware and software platform of CPS driven control system for energy-intensive equipment is then briefly introduced, which adopts embedded control system, wireless network and industrial cloud. It not only realizes the functions of computer control system using DCS (PLS), optimization computer and computer for abnormal condition identification and self-optimized tuning, but also achieves the functions of mobile and remote monitoring for industrial process.

Then, using fused magnesium furnace as an example, a hybrid simulation system for CPS driven control system for energy-intensive equipment developed by our team is introduced. The results of simulation experiments show the effectiveness of the proposed method that integrates the setpoint control, tracking control, self-optimized tuning and remote and mobile monitoring for operating condition in the framework of CPS.

The industrial application of the proposed CPS driven control system is also discussed. It has been successfully applied to the largest magnesia production enterprise in China, resulting in great returns. Finally, future research on the CPS driven control system is outlined.

**Tianyou Chai** received the Ph.D. degree in control theory and engineering in 1985 from Northeastern University, Shenyang, China, where he became a Professor in 1988. He is the founder and Director of the Center of Automation, which became a National Engineering and Technology Research Center and a State Key Laboratory. He is a member of Chinese Academy of Engineering, IFAC Fellow and IEEE Fellow. His current research interests include modeling, control, optimization and integrated automation of complex industrial processes.

He has published 200 peer reviewed international journal papers. His paper titled Hybrid intelligent control for optimal operation of shaft furnace roasting process was selected as one of three best papers for the Control Engineering Practice Paper Prize for 2011-2013. He has developed control technologies with applications to various industrial processes. For his contributions, he has won 4 prestigious awards of National Science and Technology Progress and National Technological Innovation, the 2007 Industry Award for Excellence in Transitional Control Research from IEEE Multiple-conference on Systems and Control, and the 2017 Wook Hyun Kwon Education Award from Asian Control Association.

# IEEE ICMA 2019 Conference

## Plenary Talk 2

**Does the progress of robotics pass through soft materials?**

**Cecilia Laschi, Ph.D.**

Professor, Deputy Director

The BioRobotics Institute

Scuola Superiore Sant'Anna, Rector's delegate to research

e-mail: [cecilia.laschi@santannapisa.it](mailto:cecilia.laschi@santannapisa.it)

<https://www.santannapisa.it/en/node/3934>



### ***Abstract:***

Though a young discipline, robotics progressed rapidly and pervaded our lives more than we perceive, becoming a tool we cannot do without in manufacturing. Futuristic scenarios have been proposing robots in daily life of citizens and professionals for decades, creating expectations that have not yet been matched. What are the realistic scenarios that robotics technologies enable today? What are the abilities



that robots still miss to match expectations for extensive application and healthier and safer human life? Largely inspired by the observation of the role of soft tissues in living organisms, the use of soft materials for building robots is recognized as one of the current challenges for pushing the boundaries of robotics technologies and building robotic systems for service tasks in natural environments. The study of living organisms sheds light on principles that can be fruitfully adopted to develop additional robot abilities or to facilitate more efficient accomplishment of tasks, because living organisms exploit soft tissues and compliant structures to move effectively in complex natural environments.

Robots have a great potential for becoming part of our lives, for responding to current societal challenges, for contributing to economic growth. New materials and new forms of machine intelligence are key directions for the future robotics progress.

**Cecilia Laschi** is Full Professor at the BioRobotics Institute of Scuola Superiore Sant'Anna in Pisa, Italy, where she serves as Rector's delegate to Research. She graduated in Computer Science at the University of Pisa in 1993 and received the Ph.D. in Robotics from the University of Genoa in 1998. In 2001-2002 she was JSPS visiting researcher at Waseda University in Tokyo.

Her research interests are in the field of soft robotics, a young research area that she pioneered and contributed to develop at international level, including its applications in marine robotics and in the biomedical field. She has been working in humanoid robotics and neurorobotics, at the merge of neuroscience and robotics.

She is in the Editorial Boards of several international journals. She serves as reviewer for many journals, including Nature and Science, for the European Commission, including the ERC programme, and for many national research agencies.

She is senior member of the IEEE, of the Engineering in Medicine and Biology Society (EMBS), and of the Robotics & Automation Society (RAS), where she served as elected AdCom member and currently is Co-Chair of the TC on Soft Robotics. She founded and served as General Chair for the IEEE-RAS First International Conference on Soft Robotics in Livorno, in April 24-28, 2018.

She is founding member of RoboTech srl, spin-off company of the Scuola Superiore Sant'Anna, in the sector of edutainment robotics.

# IEEE ICMA 2019 Conference

## Plenary Talk 3

### The New Wave in Robot Grasping

**Ken Goldberg, Ph.D.**

Professor and Director

William S. Floyd Jr. Distinguished Chair in Engineering

Department Chair, Industrial Engineering/Operations Research (IEOR)

Director, AUTOLAB and CITRIS "People and Robots" Initiative Founding  
Member, Berkeley AI Research (BAIR) Lab Joint Appointments:  
EECS, Art Practice, School of Information (UC Berkeley) and Radiation  
Oncology (UC San Francisco Medical School).

University of California, Berkeley

E-mail: [goldberg@berkeley.edu](mailto:goldberg@berkeley.edu)    <http://goldberg.berkeley.edu>





***Abstract:***

Robots are about to become far more dextrous based on a new wave in research that combines classical mechanics, stochastic, and deep learning.

Despite 50 years of research, robots remain remarkably clumsy, limiting their reliability for warehouse order fulfillment, robot-assisted surgery, and home decluttering. The First Wave of grasping research is purely analytical, applying variations of screw theory to exact knowledge of pose, shape, and contact mechanics. The Second Wave is purely empirical: end-to-end hyperparametric function approximation (aka Deep Learning) based on human demonstrations or time-consuming self-exploration. A "New Wave" of research considers hybrid methods that combine analytic models with stochastic sampling and Deep Learning models. I'll present this history with new results from our lab on grasping diverse and previously-unknown objects and discuss exciting future research including cloud and fog robotics.

**Ken Goldberg** is an artist, inventor, and UC Berkeley Professor focusing on robotics. He was appointed the William S. Floyd Jr Distinguished Chair in Engineering and serves as Chair of the Industrial Engineering and Operations Research Department. He has secondary appointments in EECS, Art Practice, the School of Information, and Radiation Oncology at the UCSF Medical School. Ken is Director of the CITRIS "People and Robots" Initiative and the UC Berkeley AUTOLAB where he and his students pursue research in machine learning for robotics and automation in warehouses, homes, and operating rooms. Ken developed the first provably complete algorithms for part feeding and part fixturing and the first robot on the Internet. Despite agonizingly slow progress, he persists in trying to make robots less clumsy. He has over 250 peer-reviewed publications and 8 U.S. Patents. He co-founded and served as Editor-in-Chief of the IEEE Transactions on Automation Science and Engineering. Ken's artwork has appeared in 70 exhibits including the Whitney Biennial and films he has co-written have been selected for Sundance and nominated for an Emmy Award. Ken was awarded the NSF PECASE (Presidential Faculty Fellowship) from President Bill Clinton in 1995, elected IEEE Fellow in 2005 and selected by the IEEE Robotics and Automation Society for the George Saridis Leadership Award in 2016.

More information can be obtained in <http://goldberg.berkeley.edu>

# **IEEE ICMA 2019 Conference**

## **Keynote Speech**

### **Cell Processing Task Automation**

**James K. Mills, Ph. D.**

Professor

Department of Mechanical and Industrial Engineering

University of Toronto

5 King's College Rd. Toronto, Ontario Canada

Email: [mills@mie.utoronto.ca](mailto:mills@mie.utoronto.ca)

<http://www.mie.utoronto.ca/labs/nonlin/mills2.html>



***Abstract:***

Interest has grown rapidly over the last decade in biological research and clinical applications involving manipulation and processing of single cells. In research labs a variety of single cell processes are routinely conducted including removal of cell organelles, transfer of RNA, DNA and proteins into the cell and removal of human embryonic cells formed during cell cleavage, amongst others. Currently, much of this cell processing work is carried out manually by highly skilled technicians. This presentation summarizes some of our recent work directed towards the automation of biological micro-scale tasks using robotic technology. The work presented will address control and automation methods utilized to achieve automation of single cell surgery as well as other cell processing automation methods.

**James K. Mills** is with Department of Mechanical and Industrial Engineering, University of Toronto. He received the PhD in Mechanical Engineering, specializing in robotic control. His recent research interests include: 3D MEMS robotic assembly, meso-scale machine design, control and automation of micro-scale biological tasks. He has published over 450 papers. He has been an Invited Visiting Professor at the Centre for Artificial Intelligence and Robotics in Bangalore, India, a Visiting Professor at the Hong Kong University of Science and Technology, Chinese University of Hong Kong and the City University, Hong Kong.

# IEEE ICMA 2019 Conference Workshop

## World Premium Workshops on Robotics

Sunday, August 4, 2019

14:00 - 15:40

Conference Room 1, 1F

Tianjin Shangri-La Hotel, Tianjin, China

### Regional Analysis of Distributed Parameter Systems and Their Applications for the Control of Cyber–Physical Systems

**Venue:** Conference Room 1, 1F

Tianjin Shangri-La Hotel, Tianjin

**Date and Time:** 14:00 - 15:40, August 4, 2019

#### **Organizers:**

Dr. YangQuan Chen, University of California, Merced, USA

Dr. Fudong Ge, China University of Geosciences, Wuhan, PR China

#### **About the workshop:**

It is well known that Cyber-physical systems (CPSs) with integrated computational and physical processes can be regarded as a new generation of control systems and can interact with humans through many new modalities. The objective of CPS is to develop new science and engineering methods in which sensor and actuator configurations, and physical designs are compatible, synergistic, and integrated at all scales. Many CPSs are characterized by parameters and variables that depend both on time and location so that distributed parameter systems (DPSs) governed by partial differential equations (PDEs) can be used to adequately represent the cyber-physical process dynamics. Moreover, due to the strong interactions between components in these DPS dynamics, there are cases when the

system is not controllable or observable in the whole domain of interest but can be controllable and observable in a subdomain. Thus, regional analysis makes more practical sense. Regional sensing and actuation is getting more and more important in this CPS age with cloud computing and big data movements.

This workshop will prepare the IEEE ICMA 2019 audience with 1) compelling reasons why this research theme is important, 2) what are basic concepts and existing results, and 3) what are rich future research opportunities.

### **List of Speakers and Schedule**

<b>Time</b>	<b>Topics</b>	<b>Speaker List</b>
13:55-14:00	Welcome speech	
14:00-14:30	Regional analysis of DPSs and Their Applications for the control of CPSs – 25 years in review	Dr. YangQuan Chen, University of California, Merced, USA
14:30-15:00	Why we should use regional analysis: From MAS-net project to CPS to CHS	Dr. YangQuan Chen, University of California, Merced, USA
15:00-15:30	Regional analysis of fractional order DPSs and Their Applications for the control of CPSs –(Ge)	Dr. Fudong Ge, China University of Geosciences, Wuhan, PR China
15:30-15:40	Panel Discussion	Moderators: All speakers

# IEEE ICMA 2019 Conference Workshop

Regional Analysis of Distributed Parameter Systems and Their  
Applications for the Control of Cyber–Physical Systems

## The Workshop speakers

### **Dr. YangQuan Chen, Professor**

Mechatronics, Embedded Systems and Automation (MESA) LAB,

Dept. of Mechanical Engineering, School of Engineering

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# Table of Contents

MA1-P	Poster Session (Intelligent Mechatronics and Automation)	
	<a href="#">An Experimental Study on Burrs in Micro Milling Antenna Micro Narrow Slots</a>	1
	<i>Yu Cao, Chaoyang Wang, Yuan Ping, Peng Hou, Weishe Wu</i>	
	<a href="#">Optimization of Spectroscope Parameters for Single-beam Pulsed Laser Scanning Circumferential Detection System</a>	6
	<i>Yanliang Gao, Bingting Zha, Jinbo Huang, Hailu Yuan</i>	
	<a href="#">A Path Planning Strategy for Intelligent Sweeping Robots</a>	11
	<i>Hongmei Zhang, Wei Hong, Mingjie Chen</i>	
	<a href="#">Dynamic Analysis and Simulation of a Deformable Wheeled Jumping Robot</a>	16
	<i>Hequan Wang, Han Li, Changlong Ye, Guanglin Ding</i>	
	<a href="#">Research on Energy Saving Principle of Pumping Unit Driven by Wind Turbine</a>	21
	<i>Lihua Wang, Chunyou Zhang, Chunyou Zhang</i>	
	<a href="#">Exponential Stability Criterion for Vehicle Nonlinear Uncertain Suspension Systems with Time-Varying Delay</a>	27
	<i>Binqiang Li, Guangtian Shi, Yanliang Cui, Rui Shi, Kaiyun Wang, Lanlan Xu</i>	
	<a href="#">Variable Structure Control for the Roll Stabilization of the AUV During the Diving Process with a Constant Speed</a>	33
	<i>Zhigang Qi, Yuan Chen, Wei Zhao</i>	
	<a href="#">DSC and LADRC Path Following Control for Dynamic Positioning Ships at High Speed</a>	39
	<i>Guoqing Xia, Hongfei Chu, Yunan Shao, Binyuan Xia</i>	
	<a href="#">Improved PRM for Path Planning in Narrow Passages</a>	45
	<i>Kai Cao, Qian Cheng, Song Gao, Yangquan Chen, Chaobo Chen</i>	
	<a href="#">Mechanism Analysis and Simulation Study of Static Difference Generated by Proportional Controller</a>	51
	<i>Jiayao Wang, Xuesong Zhou, Youjie Ma</i>	
	<a href="#">Static Error Mechanism Analysis and Simulation Research Based on PI Control</a>	58
	<i>Xuesong Zhou, Yongliang Zhou, Youjie Ma</i>	
	<a href="#">Real-time Obstacle Avoidance and Person Following Based on Adaptive Window Approach</a>	64
	<i>Minfeng Cen, Yonglong Huang, Xunyu Zhong, Xiafu Peng, Chaosheng Zou</i>	
	<a href="#">Robust Optimization Models of Integrated Configuration Design and Scheduling for</a>	70



Reconfigurable Flowline	
<i>Jianping Dou, Xia Zhao, Qi Sun</i>	
Study on Cooperative Control Algorithm of Two Spherical Amphibious Robots	76
<i>Liang Zheng, Shuxiang Guo, Yan Piao, Shuoxin Gu, Ruochen An, Wenbo Sui</i>	
Fish Population Status Detection Based on Deep Learning System	81
<i>Baofeng, Zhang, Fuhua Xie, Fangfang Han</i>	
Study on Visual Detection Device of Plant Leaf Disease	86
<i>Ning Fu, Chong Wang, Xiaowen Ji</i>	
Automatic Extraction Tracking and Control of Robotic Based on Mean-shift	91
<i>Yang Zhang, Xiukun Wang</i>	
Research on Multiple Blind Watermarking Algorithm Based on Double Scrambling	97
<i>Hui Wang, Qiang Wang, Lijun Yu, Fei Zhong</i>	
Design of Distributed Control System for the Pick-up Robot Based on CAN Bus	102
<i>Rui Chen, Biao Liu, Man Pan, Haibo Zhou</i>	
Finite Element Analysis on the Orthodontic Treatment of Loose Tooth with Overlapping by Periodontal Splint	108
<i>Chunqiu Zhang, Zhongxin Li, Yang Song, Xue Shi, Xinyue Li</i>	
Study on a High G Mechanical Device for Animal Experiments	114
<i>Kangning Li, Lu Cui, Haiying Liu, Chunqiu Zhang, Xizheng Zhang</i>	
Dynamic Behavior of the Discharge Valve in A Moving Coil Oil-free Linear Compressor for Refrigeration Cycle	120
<i>Chengzhan Li, Jinghui Cai</i>	
Evaluation Index and Method of Equipment Utilization Rate in Distribution Network with the Integration of PV	125
<i>Yang Yang, Qi Gong, Chao Lv, Shan Guo, He Li, Wenchao Cai</i>	
Mapping of an Enclosed Underwater Environment by Acoustic Side-scan	130
<i>Yibin Peng, Dr Peter N Green</i>	
Industrial Robot Optimal Time Trajectory Planning Based on Genetic Algorithm	136
<i>Guohong Li, Yuanliang Wang</i>	
Construction of Welding Quality Intelligent Judgment System	141
<i>Jinjin Guo, Yang Liu, Gang Wu</i>	
A Fast Calculation Method of Eccentricity of Rotary Parts Based on Least Squares	146

<i>Sanying Zhu, Qiang Liu, Pengpeng Sun, Jian Wang</i>	
Research on The Design of Terminal for EV DC Charging Coupler	152
<i>Wenjia Sun, Jiaojiao Wang, Xiao Li, Yang Li</i>	
Effects of Loading Frequency on the Mechanical Response Properties of Osteocytes in Microgravity Environment	158
<i>Sen Zhao, Haiying Liu, Yang Song, Yonghe Li, Chunqiu Zhang</i>	
Practical Kicking Motion Generation Method for NAO	163
<i>Chaojun Wang, Wenchuan Jia, Yi Sun, Shugen Ma</i>	
Virtual Simulation Test of on-board Electronic Equipment under Mechanical Environment	169
<i>Yahong Dong, Yuejin Shang</i>	
Basic Experiments for a Remote Control Robot-Mapping System in Complex Environment	174
<i>Li Ke, Tingxin Song, Nattawat Pinrath, Darren Phang Ren Yee, Nobuto Matsuhira</i>	
A Coupling Simulation of Converter Field Circuit for Active Radial Electromagnetic Bearing Based on Simplorer and Maxwell	180
<i>Yibin Li, Jian Zhou, Haipeng Geng, Tingchen Du, Yonghong Qi, Xiliang Yin</i>	
Multi-Sensor Integrated Navigation System for Ships Based on Adaptive Kalman Filter	186
<i>Bo Fu, Junsheng Liu, Qishuang Wang</i>	
Analysis of Thermal Characteristics of 10Kw High Speed Permanent Magnet Synchronous Motor	192
<i>Xiliang Yin, Haipeng Geng, Hao Lv, Hao Xu, Yonghong Qi</i>	
A Study on Moving Window Adaptively Weighting Estimation Method	198
<i>Yi Gao, Ya Gao, Yanhui Mao</i>	
Application of a Combined Denoising Method in Ground Penetrating Radar Signal Pre-processing	203
<i>Dingjie Xu, Yuxuan Wu, Feng Shen</i>	
Biocompatibility of Ti Coatings with Varied Thicknesses on Ti Alloy Substrates using Osteoblasts	208
<i>Xin Wang, Zheng He, Jinduo Ye, Chunqiu Zhang</i>	
Design and Analysis of Dual-arm Cooperative Robot System for Hole-axis Assembly	213
<i>Bin Li, Yuhang Wang, Shoujun Wang, Qi Li, Yong Yang</i>	
An Adaptive Contrast Threshold SIFT Algorithm Based on Local Extreme Point and Image Texture	219
<i>Yunwei Jia, Kun Wang, Chenxiang Hao</i>	

<a href="#">A New Saliency Object Extraction Algorithm Based on Itti's Model and Region Growing</a>	224
<i>Yunwei Jia, Chenxiang Hao, Kun Wang</i>	
<a href="#">Numerical Simulation of Sand Concentration and Pressure Distribution in Sand Experimental Box</a>	229
<i>Youshi Xuchen, Bingting Zha, Zhen Zheng, Hailu Yuan</i>	
<a href="#">Restaurant Serving Robot with Double Line Sensors Following Approach</a>	235
<i>Vo Nhu Thanh, Dang Phuoc Vinh, Ngo Thanh Nghi, Le Hoai Nam, Do Le Hung Toan</i>	
<a href="#">Research on Control Effect of Window Glass on Inner Sound Environment of High-speed Train</a>	240
<i>Zhengxiao Xu, Guangtian Shi, Xungang Diao, Xiaoan Zhang, Zhidan Huang, Huanhuan Zhang</i>	
<a href="#">A New QR Code Multi-layer Encryption System based on Image Geometric Processing</a>	246
<i>Mingyin Xu, Lianrong Lv, Jiawei Zhang, Mengqi Xu, Chaosen Zhang, Jianfeng Zhang</i>	
<a href="#">Target Approach for an Autonomous Mobile Robot Using Camera Images and Its Behavioral Acquisition for Avoiding an Obstacle</a>	251
<i>Yuta Takashima, Keigo Watanabe, Isaku Nagai</i>	
<a href="#">A Fast Pose Estimation Method Based on New QR Code for Location of Indoor Mobile Robot</a>	257
<i>Xuwei Cao, Yiping Yang, Tao Lu, Lixin Fang, Jixiang Zhang</i>	
<a href="#">A Traffic Control Strategy of the Heavy-duty AGVS in a Square Topology</a>	263
<i>Fei Pan, Qiyuan Sun</i>	
<a href="#">Modal Analysis of Center Frame Structure of Electric Wheelchair</a>	269
<i>Lianyu Zhao, Yuping Wang, Jutao Wang</i>	
<a href="#">Ship Detection Based on Deep Learning</a>	275
<i>Yuchao Wang, Xiangyun Ning, Binghan Leng, Huixuan Fu</i>	
<a href="#">Data Transmission and Management System for Robotized Welding Station</a>	280
<i>Jinjin Guo, Song Jin, Enhong Xing, Gang Wu, Ming Lei, Shuying Yang, Teresa Zielinska</i>	
<a href="#">Design Study of 6-DOF Grinding Robot</a>	285
<i>Weimin Ge, Liang Li, Enhong Xing, Ming Lei, Shuying Yang, Teresa Zielinska</i>	
<a href="#">Trajectory Tracking Control of Multi-AUVs Formation based on Virtual Leader</a>	291
<i>Juan Li, Xu Zhang, Honghan Zhang, Xue Du</i>	
<a href="#">Stability Analysis and Observer-Based Controller Design for Uncertain T-S Fuzzy Systems with Disturbance and Time-Delay</a>	297

<i>Rui Shi, Guangtian Shi, Yanliang Cui, Binqiang Li, Xiaoyun Zhang, Lanlan Xu</i>	
<a href="#">A Research Review on Wave Modeling and Simulation Methods in Marine Environment</a>	303
<i>Jian Fu, Fuxiang Huang, Wei Gao, Binggang Yin, Lihui Li</i>	
<a href="#">Observer-based Event-triggered Output Feedback Control for a Class of Uncertain Nonlinear Systems</a>	308
<i>Min Jin, Fudong Ge</i>	
<a href="#">Angular Stiffness of a Trunnion Joint</a>	314
<i>Sheng Feng, Baisong Yang, Yonghong Qi, Haipeng Geng, Lie Yu</i>	
<a href="#">Dynamic Parameter Identification for Reconfigurable Robot Using Adaline Neural Network</a>	319
<i>Weimin Ge, Bingda Wang, Haozhi Mu</i>	
<a href="#">Design and Research of Flexible Joint with Variable Stiffness Based on Torsion Spring</a>	325
<i>Xiangxu Qu, Dongxing Cao, Qiang Wang, Yalin Li</i>	
<a href="#">A Sectional Auto-docking Charging Control Method for the Mobile Robot</a>	330
<i>Juzhong Zhang, Liming Cai, Yuyi Chu, Qixun Zhou</i>	
<a href="#">Influence of Variable Frequency Starting Parameters on Synchronous Motor Starting</a>	336
<i>Yonghong Qi, Haipeng Geng, Tingchen Du, Yibin Li, Xiliang Yin, Hao Xu</i>	
<a href="#">Feature Matching Algorithm Design and Verification in Rotates Camera Normal Region Based on ROS System</a>	342
<i>Ying Mi, Shihua Yuan, Xueyuan Li, Junjie Zhou, Xufeng Yin</i>	
<a href="#">Design of Mechanical Arm-motor Control System Based on DSP</a>	348
<i>Yanjuan Wu, Yanbin Cheng</i>	
<a href="#">Non-linear Observer Design for Ship Based on Covariance fitting for square-root cubature Kalman Filter</a>	354
<i>Xiaogong Lin, Zhiyu Liu</i>	
<a href="#">The Biomechanical Response of Cervical Spine under Different Follower Loads</a>	360
<i>Chengfei Du, Xinyi Cai, Mengsi Sun, Chengfei Du</i>	
<a href="#">Suppression of Audiovisual Integration by Exogenous Unimodal Spatial Cue</a>	365
<i>Yanna Ren, Zhenhua Zhou, Yue Ding, Wei Nie, Weiping Yang</i>	
<a href="#">Structural Design and Kinematics Analysis of a Multi-legged Wall-climbing Robot</a>	371
<i>Bin Li, Weiqi Lu, Chaowei Kang, Shoujun Wang, Qi Li, Yong Yang</i>	
<a href="#">Biomechanical Comparison of Lateral Interbody Fusion with and without Fixation</a>	377
<i>Chengfei Du, Mengsi Sun, Xinyi Cai, Chenxi Yuchi, Chengfei Du</i>	

Respiratory Rate Estimation from the Photoplethysmogram Combining Multiple Respiratory-induced Variations Based on SQI	382
<i>Haonan Yang, Min Li, Dong He, Xinze Che, Xiaogang Qin</i>	
Design and Application of Fault Prevention System for Automobile Shock Absorber Assembly Process Based on RFID	388
<i>Shide Qian</i>	
Vibration Control for Lathe System against Deterministic and Band-limited Random Disturbances	392
<i>Fanfan Qian, Zhizheng Wu, Maotong Zhang, Tao Wang, Yuanyuan Wang, Tengfei Yue</i>	
Intelligent Bugs Mapping and Wiping (iBMW): An Affordable Robot-Driven Robot for Farmers	397
<i>Haoyu Niu, Tiebiao Zhao, YangQuan Chen</i>	
Research on a Virtual Simulation System for Master-slave Teaching of a Spraying Robot	403
<i>Kai Feng, Zhengyu Wang, Bin Zi, Daoming Wang, Sen Qian</i>	
An Improved Method for Forward Kinematics of Parallel Manipulator Based on Hybrid Strategy	409
<i>Qidan Zhu, Zheng Zhang</i>	
Analysis on The Research Status and Structure Characteristics of Castor Harvester	415
<i>Huayang Zhao, Chunyou Zhang, Huayang Zhao</i>	
Prediction of Body Temperature from Smart Pillow by Machine Learning	421
<i>Songsheng Li</i>	
Functional Brain Network Analysis during Informative Auditory Stimulus-modulated Audiovisual Integration	427
<i>Siyuan He, Yang Xi, Ning Gao, Qi Li</i>	
Model for Calculating the Target Characteristics of Synchronous Scanning Circumferential Pulsed Laser Detector	433
<i>Bingting Zha, Yanliang Gao, Jinbo Huang, Xuchen Youshi</i>	
An Improved Bat Algorithm for Job Shop Scheduling Problem	439
<i>Xiaohan Chen, Beike Zhang, Dong Gao</i>	
A Fuzzy Approach to Visual Servoing with A Bagging Method for Wheeled Mobile Robot	444
<i>Meng Xu, Haobin Shi, Kai Jiang, Lihua Wang, Xuesi Li</i>	
Modeling of Hybrid Energy Management Information Network in Vessel Integrated Power System	450
<i>You Wu, Lijun Fu, Fan Ma, Xueping Gao, Yinan Xu</i>	

<a href="#">An Improved SURF Algorithm Based on Gradient and Amplitude Pre-computation</a>	456
<i>Yanhui Wei, Pengfei Yang, Lixue Xu, Zhi Zheng</i>	
<a href="#">A Pressure Regulating System for Wheelchair Back Based on PID Algorithms</a>	463
<i>Tao Wang, Lianyu Zhao</i>	
<a href="#">Learning Pushing Skills Using Object Detection and Deep Reinforcement Learning</a>	469
<i>Wei Guo, Guantao Dong, Chen Chen, Mantian Li</i>	
<a href="#">Perfusion System for Cell-Scaffold Complex Culture in Vitro</a>	475
<i>Chunqiu Zhang, Pengfei Wu, Xin Wang, Lilan Gao</i>	
<a href="#">Topography State Analysis using Structures</a>	480
<i>Abdramane Dembélé, Xiufen Ye, Adama Mariko, Daou Ibrahima</i>	
<a href="#">Mobile Blasting Robot Obstacle Avoidance Planning</a>	485
<i>Lianyu Zhao, Yanqiang Wang, Jutao Wang</i>	
<a href="#">Amphibious Vehicle Layout Optimization based on Adaptive Elite Genetic Algorithm</a>	491
<i>Mingxiao Sun, Tiantian Luan, Jun Xu</i>	
<a href="#">Design, Fabrication and Experiments of a 3D-motion Soft Elastomer Actuator</a>	497
<i>Jian Zhang, Junjie Zhou, Shihua Yuan, Chongbo Jing</i>	
<a href="#">Monitoring and Warning for Digital Twin-driven Mountain Geological Disaster</a>	502
<i>Huan Zhang, Ruigang Wang, Chuang Wang</i>	
<a href="#">Ultrasonic Vibration Assisted Drilling in Cortical Bone Experiment: a Comparative Study of Twist Drill and Three-Point Drill</a>	508
<i>Yahui Hu, Zhiqiang Yan, Chunqiu Zhang, Qingchun Zheng, Weihua Fu</i>	
<a href="#">Simulation and Analysis on Work hardening of Mechanical repeated ruling process</a>	513
<i>Chaochao Shi, Guangfeng Shi, Guoquan Shi</i>	
<a href="#">Analysis of Influencing Factors of Pipeline Blockage in Domestic Garbage Pneumatic Conveying System</a>	519
<i>Rui Tian, Hongbo Liu, Yue Li</i>	
<a href="#">Kinematics Modeling and Analysis of a Novel Five-DoF Spraying Robot</a>	524
<i>Jiarui Wan, Zhengyu Wang, Bin Zi, Daoming Wang, Zixiang Cao</i>	
<a href="#">Simulation and Analysis of Mechanical Characteristics of a 6-DOF Spray-painting Robot</a>	530
<i>Daoming Wang, Zitong Huang, Bin Zi, Jiawei Pang, Huajian Zhang, Lei Zheng</i>	
<a href="#">Stability Control of Intermediate Frequency for A Double Cavity HCN Laser</a>	537
<i>Junjie Shen, Bin Sun, Fuyong Hu, Haiqing Liu, Yinxian Jie, Yuan Yao</i>	

<a href="#">The Effect of Aging on Attentional Networks</a>	543
<i>Yanna Ren, Zhihan Xu, Ying Zhang, Jing Li, Jianqiu Wu, Weiping Yang</i>	
<a href="#">Portable Wireless Food Safety Rapid Detection Device Based on MCU</a>	549
<i>Luyang Jin, Xiuling Yan, Jing Wang, Wenbin Zhao, Wei Wei, Jun Liu</i>	
<a href="#">Seismic Response Study of the Tower of a 3 Rotors-Horizontal Axis Wind Turbine</a>	554
<i>Linping Lu, Yiping Wang, Weimin Ge, Enhong Xing, Teresa Zielińska</i>	
<a href="#">Multi-AUV Fixed-point and Positioning Control Based on Virtual Leader</a>	560
<i>Juan Li, Ruikun Yuan, Huixin Wang, Xue Du</i>	
<a href="#">Design and Implementation of Automatic Window Closer Based on Intelligent Control Algorithm</a>	566
<i>Keping Zhang, Guangtian Shi, Zhihao Zhai</i>	
<a href="#">Structural Design and Analysis of 3-DOF Manipulator for Spraying Operation</a>	572
<i>Xinhua Zhao, Mengchen Ma, Bin Li, Qi Li, Yong Yang</i>	
<a href="#">Design of Wave Pushing Plate of Multi-Directional Wave Maker with Embeddable Wave Height Sensor</a>	578
<i>Nan Liu, Haozhi Mu, Renzhe Wei, Peng Zhang, Qingsong Ning, Tao Xue, Shoujun Wang</i>	
<a href="#">Research on Fault Diagnosis Method of Asynchronous Motor</a>	583
<i>Ya Gao, Guanghui Du, Yi Gao, Qinling Zhu, Bo Li</i>	
<a href="#">Phenological Prediction Algorithm Based on Deep Learning</a>	589
<i>Yuchao Wang, Shuhe Liu, Yunpeng Sun, Huixuan Fu</i>	
<a href="#">Study on the Effect of Relative Disparity and Horizontal Position of Two Lines of 3D Subtitles on Visual Comfort</a>	594
<i>Yan Wu, Qi Li, Hua Li</i>	
<a href="#">A basic Study on Capacity and Reaction time of Visual working memory for Elderly Memory training</a>	600
<i>Ting Guo, Yanna Ren, Yinghua Yu, Yiyang Yu, Yuuki Hasegawa, Qiong Wu, Jiajia Yang, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
<a href="#">Fuzzy PID Control Applied in Evaporator of Organic Rankine Cycle System</a>	605
<i>Zhigang Wang, Zhihao Yu, Shuang Guo, Xiuli Li</i>	
<a href="#">Design of Motor Mechanism of 126kV High Voltage Circuit Breaker and Control Strategy of Stroke Subsection</a>	610
<i>Hongkui Yan, Xin Lin, Jianyuan Xu, Tianyao Tang, Di Tang, Yan Bao</i>	
<a href="#">Three-dimensional Local Path Planning of Robot Based on AR-ANT Algorithm and B-spline</a>	615



	Curve	
	<i>Hongjun Wang, Rong Ye</i>	
	Improved ORB Algorithm used in Image Mosaic	621
	<i>Hong Yu, Yuesheng Dai</i>	
	A CMOS Fish Freshness to Continuous-Time Incremental Sigma-Delta Modulator for Monitoring Fish Freshness in Fish Markets	626
	<i>Cheng-Ta Chiang, Lian-Teng Lin</i>	
	A Wide-Range Sugar Concentration to Duty Cycle Converter with Scaling Circuits for Detecting Sugar Concentration Applications	631
	<i>Cheng-Ta Chiang, Lu-Shen Shie, Bin-Hong Wang</i>	
	A CMOS Salinity Difference to Frequency Converter with Auto-Sensitivity Selection Circuits for Applications in Aquaculture	637
	<i>Cheng-Ta Chiang, Tsung-Yuan Chen, Yi-Ting Wu</i>	
	Kinematic Analysis, Simulation and Manipulating of a 5-DOF Robotic Manipulator for Service Robot	643
	<i>Song Kang, Wusheng Chou</i>	
MP1-1	Micro and Nano Systems	
	Dexterous Vibrationless Micromanipulation by Magnetic-Field Driven Micro-gripper	650
	<i>Dan Liu, Xiaoming Liu, Pengyun Li, Xiaoqing Tang, Yuqing Lin, Qiang Huang, Tatsuo Arai</i>	
	A Novel Auto-Focusing Algorithm for Automated Cell Immobilization	656
	<i>Huipeng Zhang, Liying Su, Hongmiao Wei, Yueqing Yu, Xuping Zhang</i>	
	A Mechanic Model and Velocity Optimization of Cell Microinjection	662
	<i>Hongmiao Wei, Liying Su, Huipeng Zhang, Yueqing Yu, Xuping Zhang</i>	
	Study on Tetherless Micro-Soft Robot Based on Magnetic Elastic Composite Material	668
	<i>Hongbiao Xiang, Jiancheng Ba, Yan Li, Tilei Zhang, Shoujun Wang</i>	
	Dispersion Correction for Optical Coherence Tomography by Parameter Estimation in Fractional Fourier Domain	674
	<i>Di Liu, Yi Xin, Qin Li, Ran Tao</i>	
	Piezoelectric Single Crystal-based Nano-scale Actuator and Its Amplifying Mechanism	679
	<i>Tianlu Zhang, Zhangming Du, Chao Zhou, Zhiqiang Cao, Shuo Wang, Long Cheng, Lu Deng</i>	
MP2-1	Sensor Networks, Distributed Sensor Systems	
	Study on Circulating Tumor Cell Separation Sensing System Based on Size Selection	685

	<i>Zhe Wang, Yuanhua Yu, Qimeng Chen, Ru Zheng, Xiangkai Meng, Luyang Duanmu, Zhen Zhang, Jian Li</i>	
	<a href="#">Hybrid Encryption Algorithm Based on Wireless Sensor Networks</a>	690
	<i>Tongxu Yue, Chuang Wang, Zhi-xiang Zhu</i>	
	<a href="#">A Novel Deformation Estimation Method Based on Robust Student's t Kalman Filter</a>	695
	<i>Yonggang Zhang, Geng Xu, Guangle Jia, Yongxu He</i>	
	<a href="#">Wave Height Measuring Device Based on Gyroscope and Accelerometer</a>	701
	<i>Shoujun Wang, Lu Liu, Ruijia Jin, Songgui Chen</i>	
	<a href="#">An Optical Tactile Sensor with Structural Color Using Deep Learning Method</a>	707
	<i>Jiawen Hao, Yin Zhu, Erbao Dong</i>	
	<a href="#">Improvement and Analysis of Piezoresistive Effect Model of Suspended Graphene Pressure Sensor</a>	713
	<i>Xin Lin, Yong Zhang, Ying Liu, Xianzhe Cheng, Jing Qiu, Guanjun Liu</i>	
MP3-1	Laser Technology and Laser Processing	
	<a href="#">Simulation and Experimental Research on Residual Stress Field of Cemented Carbide YG8 by Laser Shock Processing</a>	718
	<i>Guanglin Wu, Chong Peng, Shenhua Peng, Wei Guo</i>	
	<a href="#">Research On Self-Mixing Interference Displacement Reconstruction Method Based On Ensemble Empirical Mode Decomposition</a>	723
	<i>Baofeng Zhang, Haitong Zhang, Junchao Zhu, Honghong Xu, Yan Zhao</i>	
	<a href="#">Influence of Residual Stress on Fatigue Lives of AISI9310 Gear Processed by Laser Shock Peening</a>	728
	<i>Hedong Wang, Chong Peng, Yuzhe Xiao</i>	
	<a href="#">Schattering Power of Laser in Aerosol Medium</a>	733
	<i>Hailu Yuan, Bingting Zha, Zhen Zheng, Youshi Xuchen</i>	
MP1-2	Manipulator Control and Manipulation (I)	
	<a href="#">Leader-Following Consensus of Multiple Electrohydraulic Actuators with Unknown External Disturbances</a>	738
	<i>Xiaochai Li, Fan Guo, Qing Guo</i>	
	<a href="#">End-Effector Force Estimation for Robotic Manipulators from Motor Current Measurements</a>	744
	<i>Xiaoqi Li, Yanbo Wang, Zelin Yang, Haiping Zhou</i>	
	<a href="#">Kinematics Modeling and Analysis of Manipulator Using the Dual Quaternion</a>	750

	<i>Weimin Ge, Lei Chen, Xiaofeng Wang, Enhong Xing, Teresa Zielinska</i>	
	<a href="#">A Learning Method of Dual-arm Manipulation for Cloth Folding Using Physics Simulator</a>	756
	<i>Daisuke Tanaka, Sho Tsuda, Kimitoshi Yamazaki</i>	
	<a href="#">A Motion Planning Algorithm Based on Trajectory Optimization with Workspace Goal Region</a>	763
	<i>Kai Mi, Peng Hao, Jun Zheng, Yunkuan Wang, Jianhua Hu</i>	
	<a href="#">Multi-Component Toxic Gas Monitoring System Based on Internet of Things</a>	769
	<i>Junchao Zhu, Ye Fu, Yunlong Xing, Yao Zhang, Qian Qiao</i>	
MP2-2	Manipulator Control and Manipulation (II)	
	<a href="#">A Multiple Working Mode Approach to Hammering with a Modular Reconfigurable Robot</a>	774
	<i>Vladyslav Romanyuk, Sina Soleymannpour, Guangjun Liu</i>	
	<a href="#">Autonomous Two-stage Object Retrieval Using Supervised and Reinforcement Learning</a>	780
	<i>Thibault Rouillard, Ian Howard, Lei Cui</i>	
	<a href="#">A Distant Optical-Center Binocular Servo System Based on TDNN with Online Fine-tuning</a>	787
	<i>Xuesong Jiang, Yudi Jiang, Yuehong Yin</i>	
	<a href="#">A Case Study on Automated Manipulation for Hooking Wiring of Flexible Flat Cables</a>	793
	<i>Kazuki Sano, Siguma Iijima, Kimitoshi Yamazaki</i>	
	<a href="#">A Strategy for Large Workpiece Assembly Based on Hybrid Impedance Control</a>	799
	<i>Gang He, Shicai Shi, Da Wang, Hong Liu</i>	
	<a href="#">Structural Design and Kinematics Analysis of a Heavy Load Manipulator</a>	805
	<i>Weimin Ge, Shuangshuang Zhang, Xiaofeng Wang, Enhong Xing, Teresa Zielinska</i>	
MP3-2	Manipulator Control and Manipulation (III)	
	<a href="#">Control System Design for Electromagnetic Driving Robot Used for Vehicle Test</a>	811
	<i>Gang Chen, Weigong Zhang</i>	
	<a href="#">Inverse Dynamics of a Rigid-flexible Parallel Mechanism</a>	816
	<i>Chenyang Shi, Liang Liu, Xinhua Zhao, Jiabin Wang, Lei Zhao, Zhifeng Xie, Jianling Li</i>	
	<a href="#">Sliding Mode Control for Manipulator Based on Fuzzy Switching Gain Adjustment</a>	822
	<i>Jingyi Chen, Longmiao Chen, Quan Zou</i>	
	<a href="#">Kinematics Calibration of Spraying Robot based on Laser Tracker</a>	827
	<i>Yajun Liu, Bin Zi, Zhengyu Wang, Daoming Wang, Lei Zheng</i>	
MP1-3	Biomimetic Measurement and Control in Robotics	
	<a href="#">Proposal of an Environmental Recognition Method for Automatic Parking by an Image-based CNN</a>	833

	<i>Kazuki Yamamoto, Keigo Watanabe, Isaku Nagai</i>	
	<a href="#">Development of an Anemometer to Assist a Quadrotor with Auxiliary Thrusters</a>	839
	<i>Satoshi Kato, Keigo Watanabe, Isaku Nagai</i>	
	<a href="#">The Structural Design of a Magnetic Driven Wireless Capsule Robot for Drug Delivery</a>	844
	<i>Shuxiang Guo, Lining Zhang, Qiuxia Yang</i>	
	<a href="#">Development of a Leaping Mechanism for Electric Skateboards</a>	850
	<i>Toshiki Aoki, Isaku Nagai, Keigo Watanabe</i>	
	<a href="#">An Adaptive Control for Pure-feedback Systems with Non-linearly Parameterized Uncertainty</a>	856
	<i>Shixin Li, Halliang Zhou, Shun Gao, Yong Ran</i>	
	<a href="#">Real-time Dynamic Monitoring of a Multi-robot Cooperative Spraying System</a>	862
	<i>Jingfeng Pan, Bin Zi, Zhengyu Wang, Sen Qian, Daoming Wang</i>	
MP2-3	Human-System Interaction and Interface (I)	
	<a href="#">Tactile Servo Based on Pressure Distribution</a>	868
	<i>Chen-Ting Wen, Jun Kinugawa, Shogo Arai, Kazuhiro Kosuge</i>	
	<a href="#">The Identification and Evaluation for Animal and Other Sounds: The Effect of Presentation Time</a>	874
	<i>Qingqing Li, Qiong Wu, Jiajia Yang, Yiyang Yu, Fengxia Wu, Wu Wang, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
	<a href="#">Influence of Different Feature Selection Methods on EMG Pattern Recognition</a>	880
	<i>Anyuan Zhang, Qi Li, Ning Gao, Liang Wang, Yan Wu</i>	
	<a href="#">Visual Perception Design and Evaluation of Electric Working Robots</a>	886
	<i>Weimian Zhou, Jing Zhu, Yutao Chen, Jie Yang, Erbao Dong, Hao Zhang, Xuming Tang</i>	
	<a href="#">A Basic Study on Relationship between Facial Expression and Cuteness for Human-robot Emotional Communication</a>	892
	<i>Lichang Yao, Qi Dai, Ting Guo, Qiong Wu, Jiajia Yang, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
	<a href="#">Configuration of Laparoscope Holding Manipulator</a>	898
	<i>Xiaofei Wang, Yao Li, Jiliang Shao, Xu Zhu, Jinsong Gao</i>	
MP3-3	Human-System Interaction and Interface (II)	
	<a href="#">Continuous Estimation of a sEMG-Based Upper Limb Joint</a>	904
	<i>Dongdong Bu, Shuxiang Guo, Wenyang Gao</i>	
	<a href="#">The Effect of Spatial Consistence on Character Recognition of Brain-Computer Interface</a>	910

	<i>Jingjing Yang, Qi Wu, Xiao Dong, Xiujun Li, Qi Li, Jinglong Wu</i>	
	Research on Human Stoop Activity Energy Expenditure Detection Algorithm Based on AHRS Transducer	916
	<i>Wei Wang, Wei Wei, Zhicheng Qu, Lidan Cheng, Jihua Gu, Xichuan Lin</i>	
	Configuration Comparison and Design of an Upper Limb Exoskeleton for Robot Teleoperation	921
	<i>Chang Liu, Haiyuan Li, Qinjian Zhang</i>	
MP1-4	Neuro, Fuzzy, and Intelligent Control (I)	
	Intelligent Multi Agent System for Energy Management in the Classrooms with Grid Connected PV	927
	<i>Aryuanto Soetedjo, Yusuf Ismail Nakhoda, Choirul Saleh</i>	
	A Fuzzy Based Parallel Filtering Matching Algorithm for Gravity Aided Navigation	933
	<i>Maosu Zhao, Lingjuan Miao, Haijun Shao, Tian Dai</i>	
	Research on Fuzzy Adaptive Impedance Control of Lower Extremity Exoskeleton	939
	<i>Zhicheng Qu, Wei Wei, Wei Wang, Shijia Zha, Tianyi Li, Jihua Gu, Chunfeng Yue</i>	
	Edge Detection Algorithm based on Morphology and Grey Relation Analysis	945
	<i>Zhen Zheng, Bingting Zha, Hailu Yuan, Youshi Xuchen</i>	
	Algorithm Based on Improved Genetic Algorithm for Job Shop Scheduling Problem	951
	<i>Xiaohan Chen, Beike Zhang, Dong Gao</i>	
	Support Vectors Classification Method Based on Matrix Exponent Boundary Fisher Projection	957
	<i>Yaqin Guo</i>	
MP2-4	Neuro, Fuzzy, and Intelligent Control (II)	
	Online Learning of the Inverse Dynamics with Parallel Drifting Gaussian Processes: Implementation of an Approach for Feedforward Control of a Parallel Kinematic Industrial Robot	962
	<i>Tim-Lukas Habich, Daniel Kaczor, Svenja Tappe, Tobias Ortmaier</i>	
	Fusion Method of Convolutional Neural Network and Support Vector Machine for High Accuracy Anomaly Detection	970
	<i>Fusaomi Nagata, Kenta Tokuno, Kento Nakashima, Akimasa Otsuka, Takeshi Ikeda, Hiroyuki Ochi, Keigo Watanabe, Maki K. Habib</i>	
	Position Adjustment Control of A Nursing-care Robot Holding A Patient in Its Arms	976
	<i>Yang Li, Shijie Guo, Toshiharu Mukai</i>	
	PCA-CIPSO-GRNN-Based Cyclic Cooling Water Corrosion Prediction	982

	<i>Chao Dong, Zeyao Feng, Jingxian Li</i>	
	<a href="#">User-depth Customized Men's Shirt Design Framework Based on BI-LSTM</a>	988
	<i>Manyu Tian, Zhixiang Zhu, Chuang Wang</i>	
	<a href="#">Application of Deep Learning in Interturn Short Circuit Fault Diagnosis of PMSM</a>	993
	<i>Jieqiu Bao, Sen Wang, Siyang Li, Di Tang</i>	
MP3-4	Neuro, Fuzzy, and Intelligent Control (III)	
	<a href="#">Robust Control of a Mechatronic Exoskeleton for Motion Rehabilitation</a>	998
	<i>Muhammad Tallal Saeed, Shiyin Qin</i>	
	<a href="#">Optimization of MVDC Power System of All Electric Ship Based on Hybrid Energy Storage</a>	1004
	<i>Xiuyan Peng, Luo Zhao</i>	
	<a href="#">Graph-based Analysis of Functional Brain Networks for Processing Semantic Auditory and Visual Stimuli</a>	1010
	<i>Yang Xi, Qi Li, Siyuan He, Jinxing Zhang, Mengchao Zhang, Lin Liu</i>	
	<a href="#">A Novel Feature Analysis Method for EEG Signal Classification of Attended and Unattended Audiovisual Integration</a>	1016
	<i>Yang Xi, Anyuan Zhang, Qi Li, Xingjian Yang, Mengchao Zhang, Lin Liu</i>	
MP1-5	Vision System and Robotic Vision (I)	
	<a href="#">Optimal Design of Monocular Stereo Vision System</a>	1022
	<i>Yuanhao Cheng, Sunan Wang, Dehong Yu</i>	
	<a href="#">New Real-time View Synthesis Method Using Spatiotemporal Background Information</a>	1028
	<i>Jian Li, Yubin Liu, Ge Li, Jie Zhao</i>	
	<a href="#">A Method of Performing Loop Closing Using Mask R-CNN Model in SLAM System</a>	1035
	<i>Xiangyang Chen, Zhangli Zhou, Wei Liang, Meiling Wang</i>	
	<a href="#">A Novel Recognition Algorithm in 3D Point Clouds based for on Local Spherical Harmonics</a>	1041
	<i>Cao Hui, Riwei Wang, Xianbin Wen, Jindong Zhao, Wei Chen, Xuping Zhang</i>	
	<a href="#">Extrinsic Calibration of a Monocular Camera and a Single Line Scanning Lidar</a>	1047
	<i>Quan Ye, Leizheng Shu, Wei Zhang</i>	
	<a href="#">Research on V-SLAM Methods</a>	1055
	<i>Haoxin Zhang, Biao Liu, Chuangyun Shen, Haibo Zhou, Shucheng Liu</i>	
MP2-5	Vision System and Robotic Vision (II)	
	<a href="#">Study on Motion Recognition for a Hand Rehabilitation Robot Based on sEMG Signals</a>	1061
	<i>Shuxiang Guo, Zhi Wang, Jian Guo</i>	

	<a href="#">Lithium-ion Battery Face Imaging with Contactless Walabot and Machine Learning</a>	1067
	<i>Yanan Wang, Yangquan Chen, Xiaozhong Liao, Lei Dong</i>	
	<a href="#">Hierarchical Discriminant Regression Tree algorithm based on BDPCA and its application in object recognition</a>	1073
	<i>Weimin Ge, Kaikai Yuan, Xiaofeng Wang, Gang Wu</i>	
	<a href="#">Real-time Motion Detection with High-speed Vision and Local Parallel Processing</a>	1079
	<i>Luxin Yang, Wenbo Dong</i>	
	<a href="#">Optimization of Time Domain Moving Target Detection Algorithm Based on Improved FT</a>	1085
	<i>Hui Wang, Chaoda Liu, Lijun Yu, Yizhuo Liu</i>	
	<a href="#">Face and Gender Recognition System Based on Convolutional Neural networks</a>	1091
	<i>Yuxiang Zhou, Hongjun Ni, Fuji Ren, Xin Kang</i>	
MP3-5	Vision System and Robotic Vision (III)	
	<a href="#">An Improved Genetic Algorithm based on Immune Theory in Target Segmentation of Infrared Images</a>	1096
	<i>Enzeng Dong, Hao Jian, Jigang Tong</i>	
	<a href="#">A Reading Assistant System of Chinese Text for Persons with Central Visual Field Loss</a>	1102
	<i>Yiyang Yu, Yang Feng, Meng Wang, Qiong Wu, Yulong Liu, Jijia Yang, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
	<a href="#">Contrast Discrimination of Circular Contour Patterns Across Visual Field for Virtual Reality</a>	1108
	<i>Yang Feng, Qiong Wu, Jijia Yang, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
	<a href="#">Design of Mean Shift Tracking Algorithm Based on Target Position Prediction</a>	1114
	<i>Hui Wang, Xueying Wang, Lijun Yu, Fei Zhong</i>	
MP1-6	Control Theory and Application (I)	
	<a href="#">UVMS Controller Design Based on Double Close-loop Integral Sliding Mode</a>	1120
	<i>Hua Sun, Zhi Zheng, Yanhui Wei, Shanshan Luo, Pengfei Yang, Jing Liu</i>	
	<a href="#">Modeling of Small UAV Parachute Recovery System Based on Lagrangian Method</a>	1127
	<i>Han Wu, Zhengping Wang, Zhou Zhou, Jieyu Jia, Rui Wang</i>	
	<a href="#">Simulation Study on Noise Control Algorithm in Logging While Drilling</a>	1133
	<i>Zeyang Zhang, Lin Fa</i>	
	<a href="#">Simulation and Research on Position Servo Control System of Opposite Vertex Hydraulic Cylinder based on Fuzzy Neural Network</a>	1139
	<i>Jinjin Guo, Can Ye, Gang Wu</i>	



	Identification of Hydrodynamic Derivative and Motion Modeling of Underactuated Ship Based on CFD	1144
	<i>Shouzheng Yuan, Zhilin Liu, Linhe Zheng</i>	
	Integrated Aircraft and Propulsion System Simulation for Control and Performance Optimization	1150
	<i>Min Wang, Weiqun Gu, Lijun Wei, Lionel Belmon</i>	
MP2-6	Control Theory and Application (II)	
	Study on Horizontal Path Tracking Control Method for the Spherical Amphibious Robot	1155
	<i>Shuxiang Guo, Xujiie Yang, Jian Guo</i>	
	Longitudinal Dynamic Control under Complex Driving Conditions via Fuzzy Logic Sliding-mode Control	1161
	<i>Ruiqi Zhang, Yuzhuang Zhao, Sizhong Chen, Zhicheng Wu, Lin Yang</i>	
	Research and Analysis of SOGI-QSG Integral Saturation in the Application of Grid Synchronization	1167
	<i>Guangjun Zhu, Qiping Yuan, Xiaoping Yang</i>	
	Parameters Estimation of Damage Water for Undersurface Submarine Based on Extended State Observer	1172
	<i>Haiying Nie, Changbo Liu, Kun Hu, Haifeng Huang, Bingli Tian</i>	
	Application of Active Disturbance Rejection Technology in Boost Converter	1178
	<i>Kang Li, Yunliang Wang, Xuesong Zhou, Youjie Ma</i>	
	An Adaptive Control Method for Fin Stabilizer Using Saturated Nonlinear Lift Compensation	1184
	<i>Mingxiao Sun, Tiantian Luan, Jun Xu</i>	
MP3-6	Control Theory and Application (III)	
	Research and Design of Low Voltage and High Current DC Power Supply Based on Hybrid Energy Storage	1190
	<i>Chunjie Wang, Yang Xiao, Peng Chen, Jinliang Yin</i>	
	Stroke Estimation for Linear Compressor with Energy Method	1196
	<i>Mingsheng Tang, Huiming Zou, Xuan Li, Changqing Tian</i>	
	Safety Requirements Analysis for a Launching Control System based on STPA	1201
	<i>Nan Qin, Liang Ma</i>	
	$L_1$ Gain Scheduled Adaptive Control to Water Level of Nuclear Steam Generator	1206
	<i>Junling Wang, Jie Zhou, Xiuchun Luan, Zhida Yang</i>	

MP1-7	Rotor Dynamics, Vibration Analysis and Vibration Control	
	<a href="#">Study on Vibration Characteristics of an Asymmetric Dual-rotor System</a>	1212
	<i>Jun Liu, Zhu Han, Chang Wang, Weimin Ge</i>	
	<a href="#">The Character Analysis and Testing on Vibration Noise of Permanent Magnet Synchronous Motor in Marine Electric Propulsion System</a>	1218
	<i>Lanyong Zhang, Lei Zhang, Sheng Liu, Wugui Wang</i>	
	<a href="#">Research of the Dual-rotor System with Spring Characteristics</a>	1224
	<i>Jun Liu, Chang Wang, Teresa Zielińska</i>	
	<a href="#">Investigation on the Nonlinear Dynamic Characteristics of the Air Lubricated Bearing Concerning Frequency of Perturbation Effect</a>	1230
	<i>Baisong Yang, Sheng Feng, Jiale Tian, Lie Yu</i>	
	<a href="#">An Investigation on the Stability Performance of Wave Journal Bearing Rotor System with Geometry Parameters</a>	1236
	<i>Baisong Yang, Sheng Feng, Jiale Tian, Lie Yu</i>	
	<a href="#">Study on Low-Pressure Casting Technique and Mold Design of the Aluminum Wheel</a>	1242
	<i>Jiaze Wang, Kaijie Lu, Qingchun Zheng, Wenpeng Ma, Pai Peng, Cong Chen, Jiehe Li, Peixin Li, Dawei Zheng</i>	
MP2-7	Biomimetic Systems	
	<a href="#">Subtle Vibration Sensing and Dimension Measurement with A Bio-inspired Optical Tactile Sensor</a>	1248
	<i>Yin Zhu, Jiawen Hao, Jie Yang, Erbao Dong</i>	
	<a href="#">Design of a Hierarchical Control System for Tetherless Snake Robot</a>	1254
	<i>Fenglei Ni, Yongqiang Li, Yunhu Zhou, Liangliang Zhao, Hong Liu</i>	
	<a href="#">Phase Space Reconstruction Based Multi-Task Classification for Motor Imagery EEG</a>	1260
	<i>Enzeng Dong, Kairui Zhou, Shengzhi Du</i>	
	<a href="#">Stable Control Gait Planning Strategy for A Rehabilitation Exoskeleton Robot</a>	1265
	<i>Ziming Guo, Can Wang, Zefeng Yan, Lufeng Zhang, Xunju Ma, Xinyu Wu</i>	
	<a href="#">Directing Multiphenotypic Differentiation of Rat Bone Marrow Mesenchymal Stem Cells under Mechanical Gradient Field</a>	1271
	<i>Xin Wang, Yang Li, Chunqiu Zhang</i>	
	<a href="#">A Novel Optimization Design Method for Multi-Degree of Freedom Vibratory Gyroscope</a>	1276
	<i>Shuying Hao, Yulun Zhu, Chenqing Zhang, Jingjing Feng, Wei Chen, Kunpeng Zhang</i>	

TA1-1	Medical, Biomedical and Rehabilitation Systems (I)	
	<a href="#">A Novel Master Manipulator with Force Feedback for Robot-Assisted Natural Orifice Transluminal Endoscopic Surgery</a>	1282
	<i>Chenglong Wang, Jianchang Zhao, Shuxin Wang, Jianmin Li, Chaoyang Shi</i>	
	<a href="#">Design and Evaluation of a Training System to Increase Knee Extension Load During Walking</a>	1288
	<i>Zixi Gu, Mazoon Salim Al Maamari, Di Zhang, Yasuo Kawakami, Sarah Cosentino, Atsuo Takanishi</i>	
	<a href="#">Design and Implementation of the Lower Extremity Robotic Exoskeleton with Magnetorheological Actuators</a>	1294
	<i>Jiajun Xu, Linsen Xu, Youfu Li, Chen Peng, Jinfu Liu, Chanchan Xu, Shouqi Chen, Yang Liu, Jian Chen</i>	
	<a href="#">Remote Tongue Based Control of a Wheelchair Mounted Assistive Robotic Arm - a proof of concept study</a>	1300
	<i>Ásgerður Arna Pálsdóttir, Strahinja Dosen, Mostafa Mohammadi, Lotte N.S. Andreasen Struijk</i>	
	<a href="#">Design and Evaluation of A New Push-type Targeted Drug Delivery Capsule Robot</a>	1305
	<i>Jian Guo, Zihong Bao, Shuxiang Guo, Qiang Fu</i>	
	<a href="#">A Finite Element Analysis of Anterior Cervical Discectomy and Fusion Compared with Percutaneous Full-endoscopic Anterior Cervical Discectomy</a>	1311
	<i>Chengfei Du, Chenxi Yuchi, Xinyi Cai, Mengsi Sun</i>	
TA2-1	Medical, Biomedical and Rehabilitation Systems (II)	
	<a href="#">Estimation of Fatigue Status by sEMG Signal Using SVM Algorithm in Massage Assessment</a>	1316
	<i>Dafan Long, Xingsong Wang, Mengqian Tian, Yuliang Mao, Yanzhong He</i>	
	<a href="#">Different Brain Activation of Phonological and Semantic Processing with Bilinguals Speakers: An fMRI Study</a>	1321
	<i>Xiujun Li, Jingjing Yang, Qi Li, Dan Tong, Jinglong Wu</i>	
	<a href="#">Radial Basis Function Neural Network-based Control Method for a Upper Limb Rehabilitation Robot</a>	1327
	<i>Shuxiang Guo, Wenyang Gao, Dongdong Bu</i>	
	<a href="#">Assessment of Pathological Grading of Bladder Cancer Using Texture Features from MRI</a>	1333
	<i>Zhe Zhou, Lin Liu, Kaiming Xue, Yue Ma, Jiayan Liu, Mengchao Zhang</i>	
TP1-1	Medical, Biomedical and Rehabilitation Systems (III)	
	<a href="#">A Method of Evaluating Rehabilitation Stage by sEMG Signals for the Upper Limb</a>	1338

	Rehabilitation Robot	
	<i>Shuxiang Guo, Huimin Cai, Jian Guo</i>	
	Evaluation Method of Linear Displacement Precision for a Rope-driven Vascular Intervention Surgery Robot	1344
	<i>Wei Zhou, Shuxiang Guo, Xianqiang Bao, Yangming Guo</i>	
	Design and Evaluation of a Novel Slave Manipulator for the Vascular Interventional Robotic System	1350
	<i>Jian Guo, Cheng Meng, Shuxiang Guo, Qiang Fu, Qi Zhan, Lei Qi</i>	
	Effects of Femur and Pelvis Material Parameters on Hip Replacement	1356
	<i>Limin Dong, Zhe Liu, Hanxiang Li, Jinduo Ye, Chunqiu Zhang, Nian Liu, Wei Chen</i>	
	Study on Robust Control for the Vascular Interventional Surgical Robot	1361
	<i>Jian Guo, Shuai Yang, Shuxiang Guo, Cheng Meng, Lei Qi</i>	
	Morphological Characteristics and Stress Analysis of 3D Printed Trabeculae	1367
	<i>Chunqiu Zhang, Lan Zhang, Xin Wang, Linwei Lv, Lu Liu, Xiankang Wang, Jinduo Ye</i>	
TP2-1	Medical, Biomedical and Rehabilitation Systems (IV)	
	Biomechanical Study of MC3T3-E1 Osteoblasts under Hypergravity	1372
	<i>Xin Wang, Wenkai Yang, Chunqiu Zhang, Jinduo Ye</i>	
	Biomechanical Study on Elastic and Viscoelastic Properties of Osteoblasts Using Atomic Force Microscopy	1377
	<i>Xin Wang, Xiaoshuang Zhang</i>	
	Biocompatibility of 3D-printed Titanium Alloy Porous Scaffold using Osteoblasts	1382
	<i>Xin Wang, Guanwen Han, Jinduo Ye, Chunqiu Zhang</i>	
	Study on Tracking Stability for a Master-Slave Vascular Interventional Robotic System	1387
	<i>Jian Guo, Lei Qi, Shuxiang Guo, Cheng Meng, Qi Zhan</i>	
	Mechanical Response of Intervertebral Disc Under Cyclic Compression	1393
	<i>Chunqiu Zhang, Tao Zhang, Qing Liu, Chengfei Du, Haiying Liu, Xin Wang</i>	
	Mechanical Test and Stability Study of Cervical Fusion Cage	1398
	<i>Ling Chen, Zhi-Wen Nian, Yu-tao Men, Jie Tian</i>	
TA1-2	Mobile Robot System (I)	
	A Novel Vascular Interventional Surgeon Training System with Cooperation between Catheter and Guidewire	1403
	<i>Shuxiang Guo, Qi Zhan, Jian Guo, Cheng Meng, Lei Qi</i>	

	<a href="#">Motion Performance of a Novel Fan Type Magnetic Microrobot in Pipe</a>	1409
	<i>Zixu Wang, Shuxiang Guo, Wei Wei</i>	
	<a href="#">Modeling and Control of a Personal Care Robot Considering Posture Adjustment</a>	1414
	<i>Guang Yang, Shuoyu Wang</i>	
	<a href="#">Study on the Path Planning of the Spherical Mobile Robot based on Fuzzy Control</a>	1419
	<i>Jian Guo, Chunying Li, Shuxiang Guo</i>	
	<a href="#">Path Planning of Omnidirectional Mobile Vehicle Based on Road Condition</a>	1425
	<i>Yazhe Ding, Hongbin Ma, Shan Li</i>	
	<a href="#">Modeling and Control of a Two-wheel Mobile Robot With Auxiliary Arms</a>	1430
	<i>Zhensheng Xie, Haitao Zhou, Haibo Feng, Songyuan Zhang, Xu Li, Jiacheng Li, Yili Fu</i>	
TA2-2	Mobile Robot System (II)	
	<a href="#">Application of ADAMS User-Written Subroutine to Simulation of Multi-gait for Spherical Robot</a>	1436
	<i>Debin Xia, Shuxiang Guo, Liwei Shi, Huiming Xing, Xihuan Hou, Yu Liu, Huikang Liu, Yao Hu, Zan Li</i>	
	<a href="#">Dynamic Modeling and Optimizing Analysis of Rigid-Flexible Coupling for Bundling Manipulator Based on ADAMS</a>	1442
	<i>Shoujun Wang, Longrui Mao, Tao Xue</i>	
	<a href="#">Design of A Negative Pressure Adsorption Pipeline Robot for Omni-directional Mobility</a>	1448
	<i>Gangfeng Liu, Hao Mo, Changle Li, Ge Li, Liyi Li</i>	
	<a href="#">Movement Performance Analysis of Mecanum Wheeled Omnidirectional Mobile Robot</a>	1453
	<i>Changlong Ye, Jianhui Zhang, Suyang Yu, Guanglin Ding</i>	
TP1-2	Mobile Robot System (III)	
	<a href="#">Model Based Control for Slip Reduction</a>	1459
	<i>Teresa Zielinska, Weimin Ge</i>	
	<a href="#">Study on Collaborative Algorithm for a Spherical Multi-robot System based on Micro-blockchain</a>	1465
	<i>Shuxiang Guo, Sheng Cao, Jian Guo</i>	
	<a href="#">Research on Gait Stability of a Foot-Type Wall-Climbing Robot</a>	1471
	<i>Zili Xu, Sijia Gu, Ming`en Zhao, Peng Bao, Hua Tian</i>	
	<a href="#">Trajectory Tracking Use Linear Active Disturbance Control of The Omnidirectional Mobile Robot</a>	1478
	<i>Huixuan Fu, Liang Xin, Bingyu Wang, Yuchao Wang</i>	

	<a href="#">A Study on Slippage and Tip-over Stability for an Omnidirectional Mobile Robot with Longitudinal MY-wheels</a>	1484
	<i>Suyang Yu, Changlong Ye, Chunying Jiang, Han Li</i>	
	<a href="#">Crawling Gait Planning Based on Foot Trajectory Optimization for Quadruped Robot</a>	1490
	<i>Shuaidong Yuan, Yijun Zhou, Chen Luo</i>	
TP2-2	Mobile Robot System (IV)	
	<a href="#">CFD-based Underwater Formation Analysis for Multiple Amphibious Spherical Robots</a>	1496
	<i>Xihuan Hou, Shuxiang Guo, Liwei Shi, Huiming Xing, Yu Liu, Yao Hu, Debin Xia, Zan Li</i>	
	<a href="#">Basic Characteristics Evaluation of a Duck-like Robot</a>	1502
	<i>Shuxiang Guo, Zan Li, Liwei Shi, Huiming Xing, Xihuan Hou, Yu Liu, Huikang Liu, Yao Hu, Debin Xia</i>	
	<a href="#">Design of a New Type of Tri-habitat Robot</a>	1508
	<i>Jian Guo, Kaitian Zhang, Shuxiang Guo, Chunying Li, Xujie Yang</i>	
	<a href="#">Implementation and Performance Assessment of Triphibious Robot</a>	1514
	<i>Yiduo Zhu, Ziyi Guo, Tao Li, Meiling Wang</i>	
	<a href="#">Research on the Image Enhancement Technology of Underwater Image of Supercavitation Vehicle</a>	1520
	<i>Xinhua Zhao, Yue Wang, Zeshuai Du, Xiufen Ye</i>	
	<a href="#">Design of a Booster Exoskeleton for Lumbar Spine Protection of Physical Workers</a>	1525
	<i>Ming Han, Tiejun Li, Shijie Wang, Tao Ma, Ningyi Ai</i>	
TA1-3	Signal and Image Processing (I)	
	<a href="#">The Impacts of Subliminal Priming Effect on Normal Choice and Questionnaire Choice</a>	1530
	<i>Qi Dai, Lichang Yao, Yiyang Yu, Qiong Wu, Jiajia Yang, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
	<a href="#">Real-Time Facial Expression Recognition Using Deep Convolutional Neural Network</a>	1536
	<i>Yuwen Zeng, Nan Xiao, Kaidi Wang, Hang Yuan</i>	
	<a href="#">Uyghur Text Detection in Natural Scene Images</a>	1542
	<i>Xinming Li, Junfang Li, Qiang Gao, Xiao Yu</i>	
	<a href="#">PICO and OS-ELM-LRF Based Online Learning System for Object Detection</a>	1548
	<i>Man Luo, Hongbin Ma, Xin Wang, Xiaofei Zhang</i>	
	<a href="#">Efficient Pose Estimation using Random Forest and Hash Voting</a>	1554
	<i>Bin Sun, Xinyu Zhang</i>	

	<a href="#">Text Detection for Natural Scene based on MobileNet V2 and U-Net</a>	1560
	<i>Kangwei Fu, Ling Sun, Xin Kang, Fuji Ren</i>	
TA2-3	Signal and Image Processing (II)	
	<a href="#">Effect Evaluation System of Massage Chair Based on EEG</a>	1565
	<i>Jiawei Li, Mengqian Tian, Yanzhong He, Xingsong Wang</i>	
	<a href="#">P300 Detection with Adaptive Filtering and EEG Spectrogram Graph</a>	1570
	<i>Hao Meng, Hongwei Wei, Tianhao Yan, Weihao Zhou</i>	
	<a href="#">3D Face Recognition Based on Deep Learning</a>	1576
	<i>Jing Luo, Fei Hu, Ruihuan Wang</i>	
	<a href="#">A Joint Classifier for Sleep Staging with Pulse Rate Variability Based on Automatic Weight Assignment</a>	1582
	<i>Dong He, Min Li, Haonan Yang, Wenbo Kang, Yanglei Ou</i>	
TP1-3	Signal and Image Processing (III)	
	<a href="#">Automated Blastomere Segmentation for Early-Stage Embryo Using 3D Imaging Techniques</a>	1588
	<i>Simarjot S. Sidhu, James K. Mills</i>	
	<a href="#">Multi-Feature Clustering Approach for Firearm Wound Identification on CT Images</a>	1594
	<i>Lian Luo, Yong Chao, Shuai Liu, Wanjun Shuai, Fei Shang</i>	
	<a href="#">Research on 3D Reconstruction Method Based on Laser Rotation Scanning</a>	1600
	<i>Tao Liu, Ningning Wang, Qiang Fu, Yi Zhang, Minghui Wang</i>	
	<a href="#">Image Fusion Processing Method Based on Infrared and Visible Light</a>	1605
	<i>Xiaogong Lin, Ronghao Yang</i>	
	<a href="#">Moving Target Detection based on Multi-feature Adaptive Background Model</a>	1610
	<i>Peiye Sun, Lianrong Lv, Juan Qin, Linghui Lin</i>	
	<a href="#">The Method of the Road Surface Crack Detection by the Improved Otsu Threshold</a>	1615
	<i>Yuwen Quan, Jie Sun, Yang Zhang, Haiwei Zhang</i>	
TP2-3	Signal and Image Processing (IV)	
	<a href="#">Design of an Ultrasonic Nondestructive Testing System for Composite Materials</a>	1621
	<i>Qinxue Pan, Xiaoyu Xu, Lang Xu, Yuping Jia, Xiaohao Liu, Dingguo Xiao, Meile Chang</i>	
	<a href="#">Study of Defect Segmentation from a Mode Background Image</a>	1626
	<i>Fangfang Han, Fuhua Xie, Baofeng Zhang, Junchao Zhu</i>	
	<a href="#">A Variable Sampling Compressed Sensing Reconstruction Algorithm Based on Texture Information</a>	1632



	<i>Lijun Yu, Fei Zhong, Hui Wang, Shuai Zhou</i>	
	<a href="#">Adaptive Filtering Fuzzy C-means Image Segmentation with Inclusion Degree</a>	1637
	<i>Hui Wang, Shuai Zhou, Lijun Yu, Jinyuan Zhao</i>	
	<a href="#">Method for Determining Grasping Position and Angle of Sea Cucumber by Rotatable Bounding Box</a>	1642
	<i>Shuguo Xiao, Xiufen Ye, Hao Chen, Wenzhi Liu</i>	
	<a href="#">The Algorithm based on the Improved Image Intensity Subtraction for the Optical Coherence Tomography Angiography</a>	1648
	<i>Yang Zhang, Jie Sun, Yuwen Quan, Haiwei Zhang</i>	
TA1-4	Industrial, Manufacturing Process and Automation (I)	
	<a href="#">Development of Variable Mold for Transition Nozzle Automation Process using TRIZ and DEFORM</a>	1653
	<i>Hui Geon Hwang, Seung Min Bae, Won Jee Chung, Sang Suk Sul, Jung Gwon Kim, I Man Kim, Seong Gi Seo</i>	
	<a href="#">Cooperative Kinematic Synchronization of a 2-Axis (Tilting/Rolling) Additional System and a 6-Axis Articulated Robot using Simulink of MATLAB and RecurDyn</a>	1659
	<i>Seung Min Bae, Hui Geon Hwang, Won Jee Chung, Sung Joo Kim, Yeon Joo Ahn</i>	
	<a href="#">Application and Experimental Verification of Practical Estimation Approach to Interpolation Cutter Path Error Caused by NC Servo Characteristics of Machining Center</a>	1665
	<i>Hua Qiu</i>	
	<a href="#">Path Generation for Robotic Polishing of Free-form Surfaces</a>	1671
	<i>Zhaosheng Li, Linlin Shang, Wei Wang, Taiwen Qiu</i>	
	<a href="#">Research on Stamping Process Parameters of Reinforcing Plate in Automobile Side Sill</a>	1677
	<i>Ling Chen, Hui Li, Yanling Wang</i>	
	<a href="#">Intelligent Workshop Bottleneck Prediction Based on Complex Network</a>	1682
	<i>Feng Zhu, Ruigang Wang, Chuang Wang</i>	
TA2-4	Industrial, Manufacturing Process and Automation (II)	
	<a href="#">A Novel Manufacturing Method for Thermoplastic Polyurethane Welding Using CO2 Laser</a>	1687
	<i>Daofu Zhang, Xingsong Wang, Mengqian Tian, Donghua Shen, Yuliang Mao</i>	
	<a href="#">Design of Bank Server Fault Diagnosis System Based on Machine Vision</a>	1692
	<i>Jun Xu, Shunyi Wu, Mingxiao Sun, Tiantian Luan</i>	
	<a href="#">The Temperature Control of Blackbody Radiation Source Based on IMC-PID</a>	1698

	<i>Lei Shao, Chang Liu, Zhigang Wang, Jinghui Wang, Xue Yang</i>	
	<a href="#">Real-Time Flow Control System Based on Siemens PLC</a>	1703
	<i>Zeyu Quan, Xin Yuan, Yuntao Zhu, Zhengyang Wang</i>	
TP1-4	Industrial, Manufacturing Process and Automation (III)	
	<a href="#">RTCP Detection for Five-Axis CNC Machine Tool Dynamic Performance Based on 8-shape Trajectory</a>	1709
	<i>Qicheng Ding, Wei Wang, Zhong Jiang, Jing Zhang, Li Du, Jiexiong Ding</i>	
	<a href="#">A Tool Path Generation Method for Three-dimensional Vibration-assisted Machining</a>	1715
	<i>Guilian Wang, Bingrui Lv, Bin Liu, Haozhi Mu</i>	
	<a href="#">Machining Parameters Optimization of Ultrasonically-Assisted Drilling Cortical Bone Based on Genetic Algorithm</a>	1721
	<i>Yahui Hu, Huaiyu Zhang, Longfei Wei, Weihua Fu, Chunqiu Zhang</i>	
	<a href="#">Simulation and Analysis of Residual Stress and Tool Wear in Mechanical Repeated Ruling Process</a>	1727
	<i>Chaochao Shi, Guangfeng Shi, Guoquan Shi</i>	
	<a href="#">An All Position Automatic Welding Machine of Large Diameter Penstock</a>	1733
	<i>Jiacheng Qi, Qiang Fu, Yifei Wu, Mo Yang, Yu Liu</i>	
	<a href="#">Pumping Unit Design and Control Research</a>	1738
	<i>Liwen Cao, Tongsen Zhao</i>	
TP2-4	Industrial, Manufacturing Process and Automation (IV)	
	<a href="#">A Hands-on Course on Mechatronics, Based on Modular Production Systems</a>	1744
	<i>Tohid Alizadeh, Mohamad Mosadeghzad</i>	
	<a href="#">Towards Enhancing Modular Production Systems by Integrating a Collaborative Robotic Manipulator</a>	1750
	<i>Mohamad Mosadeghzad, Daryn Kalym, Zhassulan Kaliyanurov, Tohid Alizadeh</i>	
	<a href="#">Rotor Design and Analysis of a High Speed Permanent Magnet Synchronous Motor for Cryogenic Centrifugal pump</a>	1756
	<i>Hao Xu, Haipeng Geng, Hao Lin, Yonghong Qi, Xiliang Yin</i>	
	<a href="#">Theoretical and Experimental Analysis of Spiral Tiled Combined Wireless Power Supply for Track Based on Electromagnetic Induction</a>	1761
	<i>Shitai Ma, Haibo Zhou, Gang Liu, Shoujun Wang, Guilian Wang</i>	
	<a href="#">Digitally Controlled Power Supply Design with Continuously Adjustable Input Voltage Based</a>	1767

	<a href="#">on UCD3138</a>	
	<i>Zhiqiang Cheng, Tao Lan, Yifei Xie, Jiaqi Fan, Huimin Liu, Zijuan Chen, Zengjia Wang</i>	
	<a href="#">Wireless Power Transmission System via Magnetic Resonance Coupling Platform</a>	1772
	<i>Yuling Ye, Chongsen Peng, Yizhang Wang, Junli Chen, Jucheng Liao, Tao Ma, Yu Liang, Mi Zhou</i>	
TA1-5	Intelligent Mechatronics and Application (I)	
	<a href="#">Intelligent Outdoor Aquaponics with Automated Grow Lights and Internet of Things</a>	1778
	<i>Zheng Jie Ong, Andrew Keong Ng, Thu Ya Kyaw</i>	
	<a href="#">Development of an Anti-Sway Positioning Controller for Rotary Cranes</a>	1784
	<i>Lihong Zhang, Zhiming Zhang, Chunquan Xu</i>	
	<a href="#">Structural Design and Test of Movable Wake Maker</a>	1790
	<i>Nan Liu, Haozhi Mu, Renzhe Wei, Peng Zhang, Qingsong Ning, Tao Xue, Shoujun Wang</i>	
	<a href="#">Finite Element Analysis and Optimization of Movable Wave Maker Based on Workbench</a>	1795
	<i>Nan Liu, Haozhi Mu, Renzhe Wei, Peng Zhang, Lili Zhao, Tao Xue, Shoujun Wang</i>	
	<a href="#">AOI Planning Method Based on Genetic Algorithm</a>	1801
	<i>Xiaohui Jia, Tao Wang, Yang Li, Jinyue Liu, Yunlong Zhang</i>	
	<a href="#">2-DOF Haptic Device based on Closed-loop EBA Controller for Gastroscope Intervention</a>	1806
	<i>Zhaoyang Xue, Chongyang Wang, Xiao He, Tao Yu, Xinyu Dong, Hao Liu</i>	
TA2-5	Intelligent Mechatronics and Application (II)	
	<a href="#">Development of Miniature Control Moment Gyroscope Engineering Prototype</a>	1812
	<i>Gang Li, Lin Lai, Wenshan Wei, Bing Xue, Jinghui Liu</i>	
	<a href="#">The Wireless Electric Vehicle System Based on Supercapacitor Power Supply</a>	1818
	<i>Tao Lan, Shengjie Cao, Zhiqiang Cheng, Qiqi Huang, Zhengchun Yang, Liqiang Xie</i>	
	<a href="#">Design of 3-D Magnetic Field Sensor and Calibration Platform for TMS</a>	1823
	<i>Hui Xiong, Hao Fu, Jianguo Zhu, Jinzhen Liu, Xiaohui Luo, Bowen Qiu</i>	
	<a href="#">Research on the Motion and Dynamics of Biomimetic Manipulator with Seven Degrees of Freedom</a>	1830
	<i>Liang Xuan, Siyuan Peng, Tianmin Guan, Ning Li</i>	
TP1-5	Intelligent Mechatronics and Application (III)	
	<a href="#">A Hybrid Stepper Motor Control Solution Based on A Low-Cost Position Sensor</a>	1836
	<i>Chuyao Zhou, Bin Liu</i>	
	<a href="#">A Method of Online Motion Generation Using Swept Volumes Collected in Advance</a>	1842

	<i>Rui Zhu, Kotaro Nagahama, Keisuke Takeshita, Kimitoshi Yamazaki</i>	
	<a href="#">A Rotor Displacement Estimation Method for Magnetic Bearings with Direct Measurement of the Ripple Current Slope</a>	1848
	<i>Zhongliang Tian, Zhengyuan Wei, Bin Guo, Yanhua Sun</i>	
	<a href="#">Embedded Toxic Gas Monitor Based on <math>\mu</math>COS-II</a>	1854
	<i>Yunlong Xing, Junchao Zhu, Ye Fu, Yao Zhang, Qian Qiao</i>	
	<a href="#">Design of a Dual-core Processor Based Controller with RTOS-GPOS Dual Operating System</a>	1859
	<i>Yuansong Sun, En Li, Guodong Yang, Zize Liang, Rui Guo</i>	
	<a href="#">Research and Design of Intelligent Traffic Signal Light Handheld Control Terminal Based on STM32</a>	1865
	<i>Xiao Chen, Feng Chen</i>	
TP2-5	Intelligent Mechatronics and Application (IV)	
	<a href="#">Design and Kinematics Analysis of Modular Soft Robot with Two-stage Driven Mechanism</a>	1871
	<i>Weimin Ge, Zhijie Pan, Haozhi Mu</i>	
	<a href="#">A Step-wise Feature Selection Scheme for a Prognostics and Health Management System in Autonomous Ferry Crossing Operation</a>	1877
	<i>Xu Cheng, Andre Listou Ellefsen, Guoyuan Li, Finn Tore Holmeset, Houxiang Zhang, Shengyong Chen</i>	
	<a href="#">Pitch Motion Control of a Soft Bionic Robot Fish Based on Centroid Adjustment</a>	1883
	<i>Weiping Shao, Chunquan Xu</i>	
	<a href="#">Research on Joint-Assisted Exoskeleton Control System of Lower Extremity in Active Spacesuit</a>	1889
	<i>Zhaoyang Li, Junyao Wang, Shengyong Yan, Peipeng Hao, Peng Tang, Yuehong Dai</i>	
	<a href="#">Application of Big Data Processing Method in Intelligent Manufacturing</a>	1895
	<i>Yao Xiao, Qiang Liu</i>	
	<a href="#">Path Planning of Sand Blasting Robot Based on Improved RRT Algorithm</a>	1901
	<i>Lianyu Zhao, Jianpeng Liu, Jutao Wang</i>	
TA1-6	Control Theory and Application (IV)	
	<a href="#">Tele-Operation of Robot using Facial Feature Point Detection</a>	1907
	<i>Masahiko Minamoto, Hidaka Sato, Takahiro Kanno, Tetsuro Miyazaki, Toshihiro Kawase, Kenji Kawashima</i>	
	<a href="#">Temperature Control of a Pulse Tube Cryocooler System Using Model Identification and</a>	1913

	<a href="#">Dynamic Matrix Control</a>	
	<i>Ziyin Chen, Zhe Lin, Han Zhang, Yu Wang</i>	
	<a href="#">Vertical Dynamics of Voice Coil Motor Active Suspension with Active Disturbance Rejection Control</a>	1919
	<i>Junlin Luo, Wei Wu, Likun Ge</i>	
	<a href="#">Research on Maximum Power Point Tracking of Pendulum Wave Energy Generator</a>	1925
	<i>Chunjie Wang, Xiaochun Zhao, Peng Chen, Lin Cui, Yunqi Duan</i>	
	<a href="#">Research on DC Bus Voltage Control of Ship Based on Hybrid Energy Storage</a>	1931
	<i>Jingnan Zhang, Ruochen Bai</i>	
	<a href="#">Analysis and Design of Self-propelled Trolley Based on Spatial RSSR Mechanism</a>	1936
	<i>Hongbiao Xiang, Yan Li, Jiancheng Ba, Tilei Zhang, Shoujun Wang</i>	
TA2-6	Control Theory and Application (V)	
	<a href="#">An Improved Power Quality Control Method of Micro-grid Converter based on Equivalent Impedance Calculation</a>	1942
	<i>Tianyi Ma, Jinyao Li, Haichao Li</i>	
	<a href="#">Virtual Current Based Direct Power Control Strategy of Dual-active-bridge DC-DC Converter</a>	1947
	<i>Xueping Gao, Lijun Fu, Feng Ji, You Wu</i>	
	<a href="#">Research on Immunity of Permanent Magnet Synchronous Motor Vector Control System</a>	1953
	<i>Guohong Li, Yongqing Xu</i>	
	<a href="#">An Improved SVPWM Modulation Strategy for Three-Level Inverter Based on 60° Coordinate System</a>	1959
	<i>Xiaojie Lou, Qiping Yuan</i>	
TP1-6	Control Theory and Application (VI)	
	<a href="#">Development of a Novel Remote Controller for Interventional Surgical Robots</a>	1964
	<i>Cheng Yang, Shuxiang Guo, Yangming Guo</i>	
	<a href="#">Pneumatic Attitude Control of the Air Bearing Testbed to Simulate the Three Axis Free Tumbling Motion of an Uncooperative Target</a>	1969
	<i>Qiang Zhang, Kemo Zhang, Yong Lu, Xiaoguang Liu, Yuanhao Yin</i>	
	<a href="#">Finite-Time Active Disturbance Rejection Control Based on High-Order Sliding Mode</a>	1974
	<i>Jianzhao Jin, Suoliang Ge</i>	
	<a href="#">Task Assignment of Heterogeneous UAV for Anti-radar Mission Using CTAP Models</a>	1980
	<i>Siqi Yi, Zhiqiang Long, Juncan Lin</i>	

	<a href="#">Disturbance Observers for General Exogenous Disturbances</a>	1986
	<i>Chuanfeng Zang, Jessada Juntawongso, Kotaro Hashikura, Md Abdus Samad Kamal, Kou Yamada</i>	
	<a href="#">Adaptive Fixed-Time Cooperative Intercept Guidance Law with Line-of-sight Angle Constraint</a>	1992
	<i>Mingjie Zhang, Jianjun Ma</i>	
TP2-6	Control Theory and Application (VII)	
	<a href="#">Multi-Robot Collaborative Coverage Under Localization Uncertainty</a>	1999
	<i>Mert Turanli, Hakan Temeltas</i>	
	<a href="#">Comprehensive Bond Graph Modeling and Optimal Control of an Anthropomorphic Mechatronic Prosthetic Hand</a>	2006
	<i>Muhammad Tallal Saeed, Sardor Khaydarov, Biniyam Legesse Ashagre, M. S. Zafar</i>	
	<a href="#">Research on Multi-USV Cooperative Search Method</a>	2012
	<i>Xiaogong Lin, Yeye Liu</i>	
	<a href="#">Research on Thrust Allocation Optimization with Main Propeller-rudder Based on Improved Genetic Algorithm</a>	2019
	<i>Guoqing Xia, Pengfei Sun, Binyuan Xia</i>	
	<a href="#">Optimal Area Keeping Control for USV based on Minimum Energy Consumption</a>	2025
	<i>Mingyu Fu, Zhiyi Liu, Yujie Xu</i>	
	<a href="#">Research on Adaptive Control of Four-Rotor Aircraft Posture Stability</a>	2031
	<i>Jiayuan Pang</i>	
TA1-7	Modeling, Simulation Techniques and Methodology (I)	
	<a href="#">State Evaluation of Large Ships Diesel Engine Based on SOM Neural Network</a>	2036
	<i>Jinxin Zhao, Jian Zhou, Peng Shang, Pengpeng Liu, Youlin Xu</i>	
	<a href="#">Microscopic Analysis of Ultrasonic Attenuation of Polymer Bonded Explosives</a>	2041
	<i>Qinxue Pan, Xiaoyu Xu, Lang Xu, Yuping Jia, Xiaohao Liu, Dingguo Xiao, Meile Chang</i>	
	<a href="#">Simulation Research on Hydraulic Energy Regulation System of Beam Pumping Unit</a>	2047
	<i>Chunyou Zhang, Lihua Wang, Huayang Zhao, Chunyou Zhang, Liang Wang</i>	
	<a href="#">Equal Load Property Simulation Analysis of Planetary Gear Transmission of Deep-Sea Geological Winch</a>	2053
	<i>Fankai Kong, Zhenyang Wang, Hengchong Ge, Binghan Wang, Huaqiu Ding</i>	
	<a href="#">Geometric Tolerance Modeling Method Based on B-spline Parameter Space Envelope</a>	2058
	<i>Chenming Song, Yijun Zhou, Chen Luo</i>	

	<a href="#">Research on the Control of Wheel-rail Noise by Wheel Sound-proof Skirt for High-speed Train</a>	2064
	<i>Huanhuan Zhang, Guangtian Shi, Xiaoan Zhang, Zhidan Huang, Xiaoyun Zhang, Zhengxiao Xu</i>	
TA2-7	Modeling, Simulation Techniques and Methodologies (II)	
	<a href="#">Research on Temperature Field of Rotor with Small Clearance of Axial-Flow High Speed PMSM</a>	2070
	<i>Baisong Yang, Sheng Feng, Jiale Tian, Lie Yu</i>	
	<a href="#">Research on Diffusion Behaviors of Leaked Natural Gas in Urban Underground Utility Tunnels</a>	2076
	<i>Chengcheng Liu, Deguo Wang, Yanbao Guo, Songzhao Zhang, Haitao Wang, Renyang He</i>	
	<a href="#">Study on the Influence of Carrier Motion of Vertical Axis Turbine Power Station on Turbine Performance</a>	2082
	<i>Fankai Kong, Binghan Wang, HuaQiu Ding, LinHui Su, Zhenyang Wang</i>	
	<a href="#">Dynamic Response Analysis of Marine Evacuation Chute System</a>	2088
	<i>Fankai Kong, Hongyang Xu, Zhenyang Wang, Hengchong Ge, BingHan Wang</i>	
TP1-7	Modeling, Simulation Techniques and Methodologies (III)	
	<a href="#">Probabilistic Simulation and Determination of Sojourn Time Distribution in Manufacturing Processes</a>	2094
	<i>Johannes Zumsande, Karl-Philipp Kortmann, Mark Wielitzka, Tobias Ortmaier</i>	
	<a href="#">Modelling of Creep Property of Base Material for Life Assessment of Mod.9Cr-1Mo Steel Welded Joint</a>	2100
	<i>Takuya Nakamura, Oga Kataoka, Hidenori Yoshimura, Hideyuki Hirata, Shuxiang Guo, Kazunari Fujiyama</i>	
	<a href="#">The Application Research of Soft Starting Technology in Marine LED Lighting System</a>	2105
	<i>Fang Liu, Zhichao Tao, Xuehui Zhang</i>	
	<a href="#">Research of Ultrasonic C-scan Imaging Lateral Resolution</a>	2111
	<i>Ran Liu, Qinxue Pan, Dingguo Xiao, Pengzhi Ma, Ming Cheng</i>	
	<a href="#">Study on the Safety Limit of Rail Corrugation of Metro Lines</a>	2116
	<i>Yukui Wang, Guangtian Shi, Zhenxin He, Xiaoan Zhang</i>	
	<a href="#">Influence of Coil Radius, Distance and Working Frequency on Efficiency in Two-Coil Magnetically Coupled Resonant Wireless Power Transmission System</a>	2121
	<i>Kun Li, Haibo Zhao, Lianrong Lv, Zhuang Sun, Yankai Shi, Yujie Hua, Qing Liu</i>	
TP2-7	Modeling, Simulation Techniques and Methodologies (IV)	



	<a href="#">Review on the Development and Applications of Vibration Isolators</a>	2126
	<i>Wei Chen, Zhen Qin, Xuping Zhang</i>	
	<a href="#">A General Method to Solve Inverse Kinematics of Spherical Wrist Manipulators</a>	2132
	<i>Jiajing Wei, Minghe Jin, Yechao Liu</i>	
	<a href="#">Related Factors and Risk Prediction of Type 2 Diabetes Complicated with Liver Cancer</a>	2138
	<i>Hui Chen, Yi Xin, Yuting Yang, Fei Li, Guoliang Cheng, Xinxin Zhang</i>	
	<a href="#">A Comparison of Methods of Data Mining Algorithms Directed Predictive Pharmacosafety Networks for Adverse Drug Event Detection</a>	2144
	<i>Xiangmin Ji, Liyan Hua, Xueying Wang, Yunfei Zhang, Jin Li</i>	
	<a href="#">Research on Passive Heave Compensation System for Synchronous Lifting and Salvage of Shipwreck</a>	2150
	<i>Jianan Xu, Shanglong Zheng, Yong Zhan, Jing Liu</i>	
	<a href="#">Impact of Inter Tine Coupling on the Spring Constant of the Quartz Tuning Fork</a>	2157
	<i>Sajid Parveez, Danish Hussain, Usman Asad</i>	
WA1-1	Medical, Biomedical and Rehabilitation Systems (V)	
	<a href="#">Performance Evaluation of a Powered Variable-stiffness Exoskeleton Device for Bilateral Training</a>	2163
	<i>Yi Liu, Shuxiang Guo, Ziyi Yang</i>	
	<a href="#">EMG-based Continuous Prediction of the Upper Limb Elbow Joint Angle Using GRNN</a>	2168
	<i>Shuxiang Guo, Ziyi Yang, Yi Liu</i>	
	<a href="#">Research on Stress-Relaxation Property of Different Layers Periodontal Ligament under Compression</a>	2174
	<i>Jinlai Zhou, Yang Song, Xue Shi, Chenguang Xu</i>	
	<a href="#">In Non-small Cell Lung Cancer, Can Radiomic Features Predict EGFR Mutations?</a>	2180
	<i>Jiayan Liu, Lin Liu, Yue Ma, Kaiming Xue, Zhe Zhou, Mengchao Zhang</i>	
	<a href="#">Application of CT Texture Analysis in Predicting Preoperative Lauren Classification of Gastric Cancer</a>	2185
	<i>Kaiming Xue, Lin Liu, Zhe Zhou, Yue Ma, Jiayan Liu, Mengchao Zhang</i>	
	<a href="#">Prediction of Benign and Malignant Thymic Tumors based on Radiomics Features</a>	2190
	<i>Yue Ma, Lin Liu, Jiayan Liu, Kaiming Xue, Zhe Zhou, Mengchao Zhang</i>	
WA2-1	<i>Intelligent Control Strategies and Algorithms</i>	
	<a href="#">Automatic Fault Detection for Marine Diesel Engine Degradation in Autonomous Ferry</a>	2195

	<a href="#">Crossing Operation</a>	
	<i>Andre Listou Ellefsen, Xu Cheng, Finn Tore Holmeset, Vilmar Aesoy, Houxiang Zhang, Sergey Ushakov</i>	
	<a href="#">Image Encryption Algorithm Based on Double Scrambling</a>	2201
	<i>Hui Wang, Qiang Wang, Lijun Yu, Jingyuan Zhao</i>	
	<a href="#">Optimum Platform Design of 3-RRR Planar Parallel Manipulators with a Parameterized Model</a>	2206
	<i>Kun Wang, Zhijiang Xie, Ruiqin Li, Shaoping Bai</i>	
	<a href="#">Reliability Evaluation of Bolt Fastening Force Based on Ultrasonic Measurement Method</a>	2212
	<i>Qinxue Pan, Ruipeng Pan, Meile Chang, Chang Shao, Xiaohao Liu, Xiaoyu Xu</i>	
	<a href="#">Moving Object Detection Based on Adaptive Loci Frame Difference Method</a>	2218
	<i>Zixuan Bai, Qiang Gao, Xiao Yu</i>	
	<a href="#">Investigation of the Gate Resistance and the RC snubbers on the EMI Suppression in Applying of the SiC MOSFET</a>	2224
	<i>Wenjie Ma, Yingzhe Wu, Hui Li, Doudou Chu</i>	
WA1-2	Medical Robots for Minimal Invasive Surgery (I)	
	<a href="#">Preliminary Design and Evaluation of Tremor Reduction Based on Magnetorheological Damper for Catheter Minimally Invasive Surgery</a>	2229
	<i>Lingling Zheng, Shuxiang Guo, Linshuai Zhang</i>	
	<a href="#">Guidewire Tracking based on Visual Algorithm for Endovascular Interventional Robotic System</a>	2235
	<i>Peng Shi, Shuxiang Guo, Linshuai Zhang, Xiaoliang Jin, Dapeng Song, Weihao Wang</i>	
	<a href="#">Tactile Training Improvement of Same-orientation but Not Different-orientation Discrimination</a>	2240
	<i>Wu Wang, Jiajia Yang, Yinghua Yu, Qiong Wu, Qingqing Li, Jiabin Yu, Satoshi Takahashi, Yoshimichi Ejima, Jinglong Wu</i>	
	<a href="#">Blood Flow Simulation of Virtual Simulation System for Vascular Interventional Surgery</a>	2245
	<i>Baofeng Gao, Lamei Shang, Xiaojuan Cai, Yuhua Jiang, Shu Yang</i>	
	<a href="#">Position-Free Hand Gesture Recognition Using Single Shot MultiBox Detector Based Neural Network</a>	2251
	<i>Jingwei Tang, Xingtian Yao, Xin Kang, Shun Nishide, Fuji Ren</i>	
	<a href="#">Dissipative Particle Dynamics Simulation of Cells Deformation under Tensile Loading</a>	2257
	<i>Xin Wang, Yandong Qu</i>	
WA2-2	Medical Robots for Minimal Invasive Surgery (II)	

	<a href="#">Development of a Grasper for Vascular Interventional Surgery Robotic System</a>	2262
	<i>Xiaoliang Jin, Shuxiang Guo, Jian Guo, Linshuai Zhang, Peng Shi, Dapeng Song, Weihao Wang</i>	
	<a href="#">Surgical Instruments Motion Safety Constraint Based on Haptic Virtual Fixture</a>	2267
	<i>Hao Qiu, Bo Pan, Yili Fu, Yue Ai</i>	
	<a href="#">A Novel Catheter Rotation Structure for Aseptic Environment of Interventional Surgery Robot</a>	2273
	<i>Kaidi Wang, Nan Xiao, Yuwen Zeng, Hang Yuan</i>	
	<a href="#">Development of Collaborative Clamping Devices for a Vascular Interventional Catheter Operation</a>	2279
	<i>Shuxiang Guo, Youchun Ma, Yan Zhao, Yuxin Wang, Jinxin Cui</i>	
	<a href="#">A Quantitative Description Method of Vascular basing on Unsupervised Learning towards Operation Skills Assessment of Endovascular Surgery</a>	2285
	<i>Jinxin Cui, Shuxiang Guo, Yan Zhao, Yuxin Wang, Youchun Ma</i>	
	<a href="#">A CNNs-based of Force and Torque Identification Model for Vascular Interventional Surgery Robot</a>	2291
	<i>Yuxin Wang, Shuxiang Guo, Yan Zhao, Jinxin Cui, Youchun Ma</i>	
WA1-3	<i>Signal and Image Processing (V)</i>	
	<a href="#">Deep CNN Framework for Environmental Sound Classification using Weighting Filters</a>	2297
	<i>Baolong Tang, Yuanqing Li, Xuesheng Li, Limei Xu, Yingchun Yan, Qin Yang</i>	
	<a href="#">A Convolutional Neural Network based on Batch Normalization and Residual Block for P300 Signal Detection of P300-speller System</a>	2303
	<i>Zhaohua Lu, Qi Li, Ning Gao, Taiyue Wang, Jingjing Yang, Ou Bai</i>	
	<a href="#">An Improved Struck Tracking Algorithm Based on Scale Adaptation and Selective Updating</a>	2309
	<i>Enzeng Dong, Mengtao Deng, Jigang Tong</i>	
	<a href="#">State and Parameter Estimation Algorithm for State Space Model Based on Linear Neural Network and Kalman Filter</a>	2314
	<i>Yuhang Yang, Ying Shi</i>	
	<a href="#">An Improved SSD Algorithm and Its Mobile Terminal Implementation</a>	2319
	<i>Enzeng Dong, Yao Lu, Shengzhi Du</i>	
	<a href="#">Low-dose CT Image Super Resolution using a Model-based Framework with CNN Prior</a>	2325
	<i>Lei Sun, Shijie Guo</i>	
WA2-3	<i>Signal and Image Processing (VI)</i>	

	Dynamic Objects Detection Based on Stereo Visual-Inertial System in Highly Dynamic Environment	2330
	<i>Jia He, Yanwu Zhai, Haibo Feng, Songyuan Zhang, Yili Fu</i>	
	Sub-pixel Gear Parameter Measurement Based on Zernike Moment	2336
	<i>Yangyang Li, Dagui Huang, Xian'gang Wu, Silei Huang, Siyuan Huang, Youcheng Li, Xunkuai Zhou</i>	
	High Speed Train Trajectory Algorithm through Fiber Optic Sensor	2342
	<i>Xiaoyue Yan, Fuyang Chen, Li Wang, Bin Jiang</i>	
	Research on Rainfall Identification Based on the Echo Differential Value from X-band Navigation Radar Image	2347
	<i>Zhizhong Lu, Boqun Lv, Lei Li, Shuyuan Guo</i>	
	Research on Optical Fiber IMU Signal Processing Based on Wavelet Algorithm	2352
	<i>Xiaogong Lin, Ruxin Guo, Yuqi Yuan</i>	
	Research on Acoustic Model of Speech Recognition Based on Neural Network with Improved Gating Unit	2358
	<i>Wei Liu, Yan Yan, Jianqiang Yu, Yiming Sun</i>	
WA1-4	Elements, Structures, and Mechanisms (I)	
	Theoretical and Numerical Analysis on the Load Capacity of Hydrodynamic Thrust Bearings with Fourier Series Decomposition	2363
	<i>Baisong Yang, Sheng Feng, Jiale Tian, Lie Yu</i>	
	Research on the Static Performance of Multi-Cantilever Foil Bearing with the Fully Coupled Elastic Hydrodynamic Solution	2369
	<i>Baisong Yang, Sheng Feng, Jiale Tian, Lie Yu</i>	
	Modeling and Coupled Vibration Analysis of Two-Span Series Dual-Rotor System	2375
	<i>Jun Liu, Ruiguo Zhu, Weimin Ge</i>	
	Mechanism Design and Curve Passing Performance Research on Walking Module of Orbital Cable Pipe Gallery Inspection Robot	2381
	<i>Jianjun Ke, Yingqiu Xu, Ruiming Qian</i>	
	Study on Mechanism of Shaft Fault Suppression Based on Squeeze Film Damper	2389
	<i>Jun Liu, Meiling Wang, Haozhi Mu, Kai Wang</i>	
	Analysis of Intelligent Vehicle Climbing Force and Battery Selection	2395
	<i>Lianyu Zhao, Zhenghan Jin</i>	
WA2-4	Elements, Structures, and Mechanisms (II)	

	<a href="#">Genetic Optimization of Thermal Management Systems for EV Power Electronics via ANSYS Multiphysics</a>	2401
	<i>Andrew J. Michalak, James K. Mills</i>	
	<a href="#">Prediction of Effective Elastic Modulus of Polymer Bonded Explosive Based on Digimat</a>	2407
	<i>Qinxue Pan, Xiaohao Liu, Lang Xu, Yuping Jia, Xiaoyu Xu, Meile Chang</i>	
	<a href="#">Maximum Torque and Limit Angular Velocity of High-speed Coupling for Interference Fit</a>	2412
	<i>Peng Shang, Yanhua Sun, Renjun Zhan, Ning Shan, Jinxin Zhao, Jian Zhou</i>	
	<a href="#">Transparent Glass-based Directional Loudspeaker</a>	2418
	<i>Yuxin Li, Limei Xu, Xuesheng Li, Xiaomei Xie, Min Chen, Cong Luo, Fang Zhu, Yalun Zhang</i>	
	<a href="#">Smoothed FE-Meshfree with Extended Moving Least-Square Method for Analysis of Reissner-Mindlin plates</a>	2423
	<i>Guangsong Chen, Jinsong Tang, Zihan Wang</i>	
	<a href="#">Compliance Analysis of a Parallel Leaf-spring Carrying Mechanism</a>	2428
	<i>Peng Li</i>	
WA1-5	Robot Navigation and Control Algorithm (I)	
	<a href="#">Vision-based Waypoints Tracking Control for an Amphibious Spherical Robot</a>	2434
	<i>Yao Hu, Liwei Shi, Shuxiang Guo, Huiming Xing, Xihuan Hou, Yu Liu, Huikang Liu, Debin Xia, Zan Li</i>	
	<a href="#">Adaptive Sliding Control for Lower Exoskeleton Robot Driven by The Series Elastic Actuator</a>	2439
	<i>Shuqiao Chen, Jianghai Zhao, Zhipeng Yu</i>	
	<a href="#">Particle Filter Algorithm for Underwater Acoustic Source DOA Tracking with Co-prime Array</a>	2445
	<i>Feibiao Dong, Limei Xu, Xuesheng Li, Shihao Wang, Xiaomei Xie</i>	
	<a href="#">Real-time Indoor Navigation of UAV Based on Visual Delay Compensation</a>	2451
	<i>Jian Li, Shaokai Xu, Yanmin Liu, Xiangdong Liu, Zhen Li, Fengdi Zhang</i>	
	<a href="#">An Improved Calibration and Compensation Method for Lever-arm Errors between Two Rotational Inertial Navigation Systems</a>	2457
	<i>Qi Wu, Kui Li, Wenwei Liang</i>	
	<a href="#">Improved JPS Algorithm Using New Jump Point for Path Planning of Mobile Robot</a>	2463
	<i>Xue Zheng, Xiaowei Tu, Qinghua Yang</i>	
WA2-5	Robot Navigation and Control Algorithm (II)	
	<a href="#">Quadrotor Vision-based Localization for Amphibious Robots in Amphibious Area</a>	2469
	<i>Huiming Xing, Shuxiang Guo, Liwei Shi, Xihuan Hou, Yu Liu, Yao Hu, Debin Xia, Zan Li</i>	

	<a href="#">LLOAM: LiDAR Odometry and Mapping with Loop-closure Detection Based Correction</a>	2475
	<i>Xingliang Ji, Lin Zuo, Changhua Zhang, Yu Liu</i>	
	<a href="#">Gain Scheduling Control of Wheel-Legged Robot LPV system Based on HOSVD</a>	2481
	<i>Jiachen Li, Haitao Zhou, Haibo Feng, Songyuan Zhang, Yili Fu</i>	
	<a href="#">Fast and Accurate Robot Localization through Multi-Layer Pose Correction</a>	2487
	<i>Yuxiang Liu, Lin Zuo, Changhua Zhang, Fenglian Liu</i>	
	<a href="#">End-to-end Decentralized Multi-robot Navigation in Unknown Complex Environments via Deep Reinforcement Learning</a>	2493
	<i>Juntong Lin, Xuyun Yang, Peiwei Zheng, Hui Cheng</i>	
	<a href="#">Speeding up FastMap for Pathfinding on Grid Maps</a>	2501
	<i>Cong Hu, Quanjun Yin, Yue Hu, Junjie Zeng, Long Qin</i>	
WA1-6	<i>Biomimetic Underwater Robots</i>	
	<a href="#">Turning Locomotion Analysis and Performance Evaluation for a Spherical Underwater Robot</a>	2507
	<i>Shuoxin Gu, Shuxiang Guo, Liang Zheng, Ruochen An</i>	
	<a href="#">Improvement and Evaluation for the Stability of Mobile Spherical Underwater Robots (SUR III)</a>	2512
	<i>Ruochen An, Shuxiang Guo, Shuoxin Gu, Liang Zheng</i>	
	<a href="#">Performance Study of an Underwater Snake-like Robot with a Flexible Caudal Fin</a>	2518
	<i>Zhong Huang, Detian Kong, Chao Ren, Shan Li, Shugen Ma</i>	
	<a href="#">Multi-Sensor Fusion Based Localization System for an Amphibious Spherical Robot</a>	2523
	<i>Yu Liu, Shuxiang Guo, Liwei Shi, Huiming Xing, Xihuan Hou, Huikang Liu, Yao Hu, Debin Xia, Zan Li</i>	
	<a href="#">A PID-type Fuzzy Logic Controller for an Interventional Surgical Robot</a>	2529
	<i>Shuxiang Guo, Yangming Guo, Xianqiang Bao, Cheng Yang</i>	
	<a href="#">Platform Design and Three-dimensional Underwater Experiment of Robotic Tuna Swimming</a>	2534
	<i>Yi Zhao, Dan Xia, Po Dai</i>	
WA2-6	<i>Rescue Robots and Field Robot Systems</i>	
	<a href="#">Mobile Robot Capable of Crossing Floors for Library Management</a>	2540
	<i>Han Yu, Lei Li, Jingge Chen, Yutong Wang, Yankun Wu, Mingyuan Li, Hui Li, Zhihong Jiang, Xiaoming Liu, Tatsuo Arai</i>	
	<a href="#">Real-time Riverbank Line Detection for USV System</a>	2546
	<i>Tianwei Feng, Junfeng Xiong, Jinchao Xiao, Jinqing Liu, Yuqing He</i>	
	<a href="#">Floor Surface Property Estimation based on Measurement of Hardness and Viscosity Using</a>	2552

Wiping-motion and Separating-motion

*Koichiro Matsumoto, Kimitoshi Yamazaki*

Development of a Hybrid Locomotion Robot for Earthquake Search and Rescue in Partially Collapsed Building 2559

*Di ZHANG, Yukitoshi MINAMI Shiguematsu, Jia-Yeu LIN, Yi-Hsiang MA, Mazoon Salim Al MAAMARI, Atsuo TAKANISHI*

Graphical Force and Haptic Feedback Teleoperation System for Live Power Lines Maintaining Robot 2565

*Jing Zhu, Yutao Chen, Ming Xu, Erbao Dong, Hao Zhang, Xuming Tang*

Design of An Inspection Robot System with Hybrid Operation Modes for Power Transmission Lines 2571

*Han Wang, En Li, Guodong Yang, Rui Guo*





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# Intelligent Multi Agent System for Energy Management in the Classrooms with Grid Connected PV

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**Abstract** - This paper presents an application of the Multi Agent System (MAS) in the Building Energy Management System, more specifically to manage the energy in the classrooms of a university. The grid connected photovoltaic (PV) is used as the electrical generation system to supply the loads in the classrooms. The objective is to minimize the electricity cost while maintaining user comfort. The MAS consists of the PV Agent, the Utility Agent, the Load Agent and the Central Control Agent. In addition, the Course Scheduler Unit is employed to inform the utilization or occupancy of the classrooms. The proposed system provides a new method to manage the energy usage from the PV by changing the temperature set-point of the air conditioner system using the Fuzzy Logic Controller. The simulation results show that the proposed system provides the highest performance index of 0.9902 in the optimization of the electricity cost and temperature comfort compared to the conventional method using a fixed temperature set-point.

**Index Terms** – Multi agent, energy management, grid connected PV.

## I. INTRODUCTION

An Intelligent Multi Agent System (MAS) is widely adopted in the distributed control systems [1]. An intelligent agent (or agent) is an autonomous system that acts in the environment to achieve its goal. An agent receives the information from the environment and takes a decision to response the changes according to the goal. In the MAS, several agents collaborate with each other to meet the global objective.

Nowadays, the development of electrical power system increases rapidly in the framework of smart grid technology. The distributed generation becomes popular due to the high penetration of renewable energy resources. Another aspect in the smart grid that attracts the attention is the energy management system. The MAS is adopted in both applications, such as for the microgrid operations [2,3], the renewable energy generation [4], the energy management in smart homes [5-7] and the buildings [8-13].

The MAS was employed to schedule smart devices in multiple smart homes [5]. The objective is to minimize the cost and peak load. In [6], the MAS was proposed to optimize energy usage in a smart home. The multi agents consist of the Management Agents, the Electrical Supply System Agents,

and the Home Appliance Agents. There are three agents in the Management Agents, i.e. the Supply Side Management Agent, which is used to manage the power from the supply systems; the Demand Side Management Agent, which is used to manage the power to the loads; and the Home Energy Management Agent, which is used to manage both Supply Side Management Agent and Demand Side Management Agent. The MAS in [7] used the Fuzzy Logic Controller (FLC) which is embedded in each agent of the home appliance. The system was developed to minimize the electricity cost while maintaining the user comfort level.

A four-layer agent consisted of the Switch Agent, the Central Coordinator Agent, the Local Controller Agent, and the Load Agent was proposed in [8] to manage energy in the commercial building. The Local Controller Agent controls the lighting and temperature of the rooms using the FLC. The Central Coordinator Agent coordinates the Switch Agent, the Local Controller Agent, and the Load Agent.

In [11] the MAS was employed in the Building Energy Management System (BEMS). The building is divided into several zones which are controlled by the agents. The agents consist of the Local Zone Agent, the Zone Agent, the On-site Generation Agent, and the Building Agent. The Local Zone Agent controls the environment at the local zone (room), which is composed of the H-agent (heating system), the V-agent (ventilation system), the C-agent (cooling system), the E-agent (lighting and electrical systems) and the U-agent (occupancy level).

Three agents namely the Generation Agent, the Load Agent, and the Storage Agent were proposed to manage the energy operation in the self-sustainable building [12]. The Generation Agent performs the following tasks: analyze and acquire the historical and weather data, control the electrical output, and power conditioning. The Load Agent optimizes the usage of loads of building by performing several tasks, such as load forecasting, appliance management, metering, and load scheduling. The Storage Agent controls the charging/discharging of the battery storage based on the state of charge (SOC) and the charging/discharging rate.

As discussed previously, the MAS in the BEMS is usually divided into the generation agents (and the storage agents), the load agents and the control agents. The loads discussed previously are the general loads in the common building such as the air conditioner, the lighting, etc. In this paper, we deal

with the BEMS in a university building, more specifically the lecture rooms or the classrooms. The building is powered by the grid connected PV system. One unique characteristic of our proposed system is that the occupancy of the classroom is well defined by the course schedule. The main contribution of our paper is in the application of MAS to optimize the energy consumed by the classrooms by maximizing the energy from the PV resources while satisfying the temperature comfort in the classrooms. It is conducted by employing the FLC to set the temperature set-point of the classroom according to the power availability of the PV system and the outdoor temperature.

The rest of paper is organized as follows. Section 2 presents the proposed system. Section 3 discusses the simulation results. The conclusion is covered in Section 4.

## II. PROPOSED SYSTEM

### A. System Overview

The configuration of the electrical system is depicted in Fig. 1, where the arrow indicates the electrical flow. As shown in the figure, the electrical power to the loads in the classrooms is supplied by the PV system and the electric utility.

In this research, to simplify the discussion, only five classrooms are considered. However, the proposed system could be extended to cope with a large number of classrooms accordingly. In each classroom, there are three kinds of loads, i.e. the air conditioner (AC), the LCD projector, and the lamps. The LCD projector and the lamps are controlled by on/off mode according to the class utilization. While the AC is a thermostat controlled, in which the temperature set-point is determined by the MAS as described in the next section.

The configuration of MAS to manage the energy consumption in the classroom is depicted in Fig. 2. The Load Agent (LA) is used to control the loads in a classroom. It sets the temperature set-point for operating the AC and switches on/off the lamps and the LCD projector based on the information from the Central Control Agent (CCA) and the Course Scheduler (CSCH). The CCA sends information about the available power of renewable resources. The Course Scheduler (CSCH) is an information system that manages the utilization of classrooms, i.e. the time schedule of the course.

The PV Agent (PVA) is an agent that is responsible to manage the power from the PV. The PVA sends the information about its power to the CCA and gets the control signal related to its power flow from the CCA. The UA is basically a simple agent to control the connection of the utility to the grid according to the signal control sent by the CCA.

CCA is the main control of the whole system. It manages the operation of the loads, the PV system and the utility. The CCA employs the FLC to generate the signal controls to the respective agents. The main objective is to maximize the power while maintaining the user comfort.

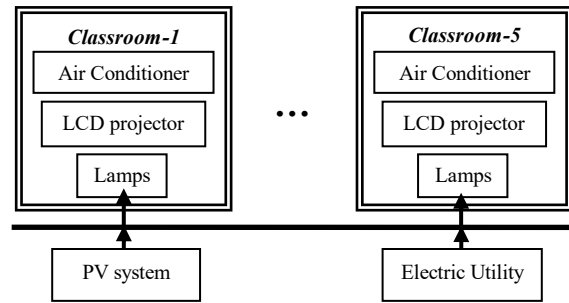


Fig. 1 Configuration of electrical system.

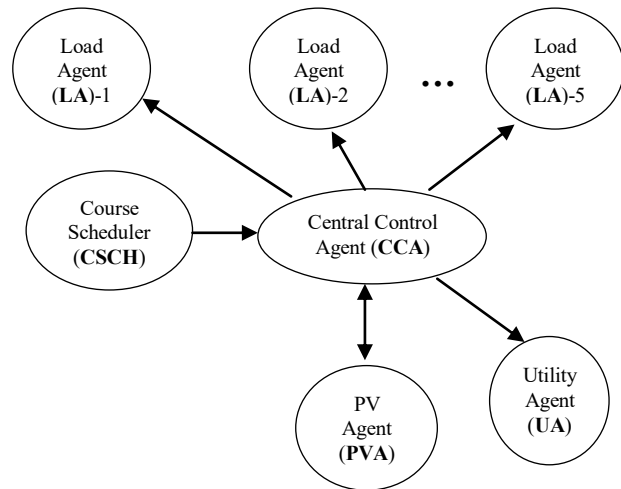


Fig. 2 Configuration of MAS.

### B. Multi Agent System

The configuration of the Load Agent (LA) is depicted in Fig. 3. All three loads (AC, lamps, LCD projector) are operated when the classroom is occupied, i.e. there is a course conducted in the classroom. The occupancy information is obtained from the CSCH.

In the current research, the operation of the Lamps and the LCD projector is just switched on/off. While the AC is operated using the thermostat control, i.e. the temperature of the classroom should follow the temperature set-point of AC. By varying the temperature set-point, the energy consumed by the AC could be managed respectively.

As shown in the figure, the agent controls the operation of the loads based on the occupancy of the classroom, the outdoor temperature and the level of renewable energy resources (RES\_LEV). The RES\_LEV data is sent by the CCA. The RES\_LEV is a value that indicates the level of availability of renewable energy resources. This value will be used by the FLC in the LA to set the temperature set-point as discussed in the next section.

The configuration of the PV Agent (PVA) is depicted in Fig. 4. PVA has two main tasks. The first task is to read the weather information and send the predicted PV power to the CCA. The second task is to read the control signal from the CCA and generate a switching signal to the power switch.

The switching signal is used to select the power flow from the PV as follows:

- Grid connection: the PV is connected to the grid
- Disconnected: the PV is disconnected from the system.

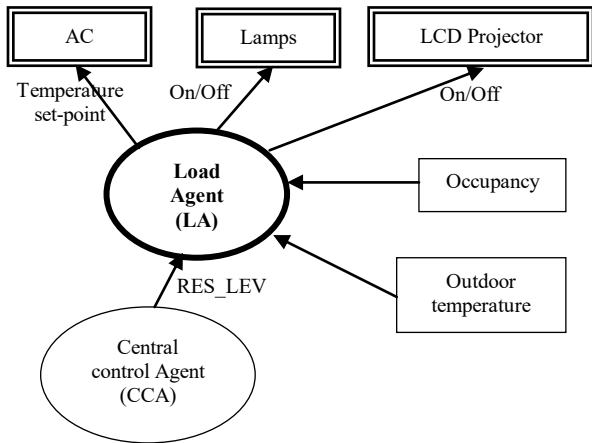


Fig. 3 Configuration of the Load Agent.

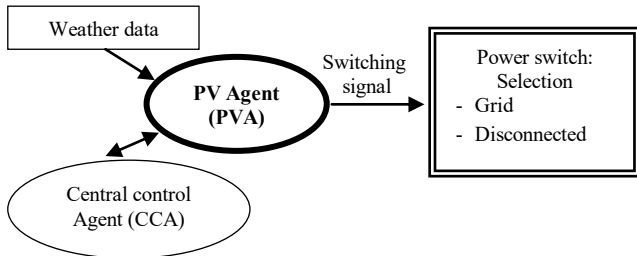


Fig. 4 Configuration of the PV Agent.

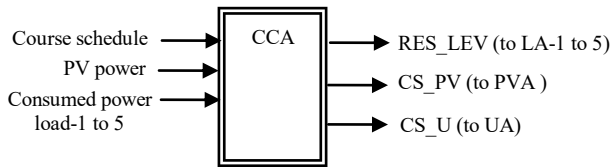


Fig. 5. The input and output of the Central Control Agent.

The CCA generates the control signals to the other agents as depicted in Fig. 5. The control signal to PVA and UA are CS<sub>PV</sub> and CS<sub>U</sub>, which are used to connect or disconnect the PV and the utility to the grid.

The control signal to the LA is RES<sub>LEV</sub> which is determined by the FLC as described in the following section.

### C. FLC in the Central Control Agent

As described previously, the CCA employs the FLC (later on is called as the FLC-CCA) to generate the control signal to the LA, the PVA, and the UA. The architecture of FLC-CCA is depicted in Fig. 6. As shown in the figure, the FLC-CCA

has two inputs and one output. The inputs are the available power from the renewable energy resources (RES<sub>PWR</sub>=PV power) and the power consumed by the loads (CONS<sub>PWR</sub>=Consumed power load-1 to 5). While the output is the level of available power from renewable energy resources (RES<sub>LEV</sub>).

The fuzzy membership functions of RES<sub>PWR</sub>, CONS<sub>PWR</sub>, and RES<sub>LEV</sub> are depicted in Fig. 7. Each variable has three linguistic values, i.e. LOW, MED, and HIGH.

Since the objective of MAS is to minimize the electricity cost by maximizing the energy usage from the RES, thus the fuzzy rules are developed in such a way to fulfill that objective. The main idea is to provide information about the availability of RES to the LA. Then the LA uses this information to determine the temperature set-point.

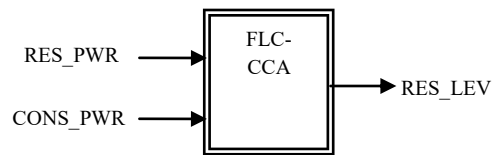


Fig. 6 FLC-CCA architecture.

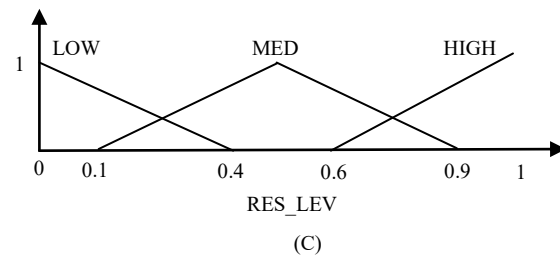
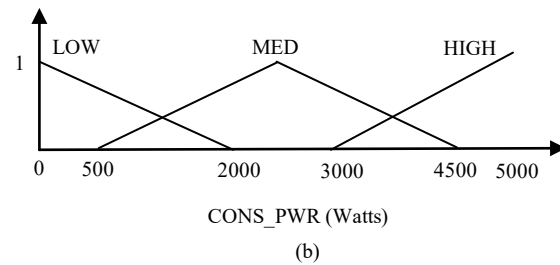
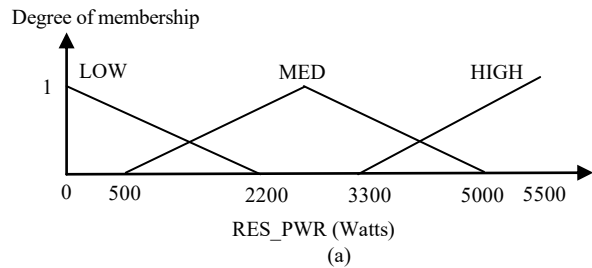


Fig. 7 Membership functions of FLC-CCA: (a) RES<sub>PWR</sub>; (b) CONS<sub>PWR</sub>; (c) RES<sub>LEV</sub>.

TABLE I  
FUZZY RULES OF FLC-CCA

$\begin{matrix} RES\_PWR \\ CONS\_PWR \end{matrix}$	LOW	MED	HIGH
LOW	MED	MED	HIGH
MED	LOW	MED	HIGH
HIGH	LOW	MED	MED

The information about the availability of RES is then called as the RES\_LEV and determined based on the RES\_PWR and CONS\_PWR. The fuzzy rules are listed in Table 1. Several rules from the table could be explained as follows:

- IF RES\_PWR is HIGH AND CONS\_PWR is LOW THEN RES\_LEV is HIGH: There is surplus power from RES, thus the RES\_LEV is set to a high level.
- IF RES\_PWR is LOW AND CONS\_PWR is HIGH THEN RES\_LEV is LOW: There is not enough power from RES, thus the RES\_LEV is set to a low level.
- IF RES\_PWR is MED AND CONS\_PWR is MED THEN RES\_LEV is MED: The availability of power from RES is medium, thus the RES\_LEV is set to medium level.

#### D. FLC in the Load Agent

The FLC in the LA (later on is called FLC-LA) is used to set the temperature set-point of the AC in the classroom as depicted in Fig. 8. This set-point is determined to satisfy two conditions: a) the temperature set-point is in the range of comfortable level; b) the availability power from RES should be extracted as much as possible.

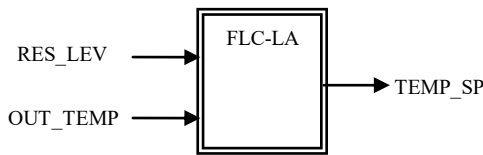


Fig. 8 FLC-LA architecture.

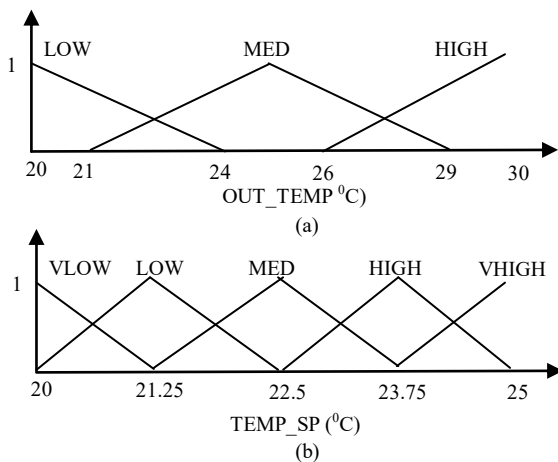


Fig. 9 Membership functions of FLC-LA: (a) OUT\_TEMP; (b) TEMP\_SP.

TABLE II  
FUZZY RULES OF FLC-LA

$\begin{matrix} RES\_LEV \\ OUT\_TEMP \end{matrix}$	LOW	MED	HIGH
LOW	VERY HIGH	MED	VERY LOW
MED	HIGH	MED	LOW
HIGH	HIGH	MED	LOW

As shown in Fig. 8, the inputs of FLC-LA are the RES\_LEV and the outdoor temperature (OUT\_TEMP). While the output is the temperature set-point (TEMP\_SP). The fuzzy membership function of RES\_LEV is the one in the FLC-CCA which is shown in Fig. 7(c). The fuzzy membership functions of OUT\_TEMP and TEMP\_SP are depicted in Fig. 9. It is noted here that the value of TEMP\_SP falls in the range of user comfortable, i.e. from 20 °C to 25 °C.

To achieve the goal of minimizing the electricity cost while allowing the temperature comfort, the fuzzy rules are defined as listed in Table 2. The rules are determined based on the idea that by increasing the temperature set-point, the energy consumed by the AC will decrease. Thus when the RES power is low, it is better to increase the temperature set-point and vice versa.

From the fuzzy rules listed in Table 2, several rules are explained as follows:

- IF RES\_LEV is LOW AND OUT\_TEMP is LOW THEN TEMP\_SP is VERY HIGH: There is a small amount power from RES, and the outdoor temperature is low, thus it is a better to set the temperature set-point to very high value for decreasing the energy consumption.
- IF RES\_LEV is HIGH AND OUT\_TEMP is HIGH THEN TEMP\_SP is VERY LOW: There is surplus power from RES, and the outdoor temperature is high, thus it suggests that the temperature set-point could be set to a very low value.

### III. SIMULATION RESULTS

To verify our proposed system, we model the system using MATLAB-SIMULINK [14]. The PV generator is simulated using the model developed in [15]. The AC and thermal system of the room are modeled based on the example given in the SIMULINK software [14]. The electrical power rating of the PV and the loads in the classroom are given in Table 3. The data for irradiation, outdoor temperature, course schedule (occupancy of the classroom) are given in Table 4.

The simulation results are depicted in Fig. 10 and Fig. 11. In Fig. 10, the profiles of RES\_LEV, outdoor temperature, temperature set-point, classroom temperature of classroom-1 are shown. For convenience, the profiles are shown from 06:00 h to 17:00 h when the classrooms are occupied. From the figure, we can see that at 07:00 h, the classroom-1 is occupied and the PV produces a small power.

Therefore the RES\_LEV is low and forces the system to set the temperature set-point to the higher value, i.e. 23 °C. At 12:00 h, when there is enough power from the PV and the consumed power is also high, then the RES\_LEV will have a medium value, i.e. 0.5. It will set the temperature set-point to the medium value, i.e. 22.5 °C.

Fig. 11 shows the profiles of consumed power of classroom-1 to classroom-5 from 06:00 h to 17:00 h. By observing the top figure, i.e. the consumed power of classroom-1, it is obtained that the consumed power in the morning is lower than the one in the afternoon. This result could be understood by examining Fig. 10 as follows. In the afternoon, the outside temperature is higher than the one in the morning. Since the temperature set-point is about 22.5 °C, the AC will consume more power in the afternoon to reach the set-point.

TABLE III  
POWER RATINGS OF GENERATOR AND LOADS

Generator and Loads	Power rating
PV	3000 W
AC	450 W (per room)
LCD projector	310 W (per room)
Lamps	240 W (per room)

TABLE IV  
IRRADIATION, OUTDOOR TEMPERATURE, OCCUPANCY OF CLASSROOM-1 TO 5

Time (hour)	Irradiation (W/m <sup>2</sup> )	Outdoor temperature (°C)	Classroom (O=occupied; X=empty)				
			1	2	3	4	5
00:00	0	21	X	X	X	X	X
01:00	0	21	X	X	X	X	X
02:00	0	21	X	X	X	X	X
03:00	0	21	X	X	X	X	X
04:00	0	21	X	X	X	X	X
05:00	0	21	X	X	X	X	X
06:00	0	22	X	X	X	X	O
07:00	200	22	O	X	X	O	O
08:00	300	24	O	O	X	O	O
09:00	500	25	O	O	X	O	O
10:00	700	26	X	O	O	X	O
11:00	900	26	X	O	O	X	O
12:00	900	26	O	O	O	X	X
13:00	800	26	O	X	O	X	O
14:00	600	27	O	X	O	O	O
15:00	400	27	X	X	O	O	O
16:00	300	24	X	X	X	O	X
17:00	0	24	X	X	X	X	X
18:00	0	24	X	X	X	X	X
19:00	0	24	X	X	X	X	X
20:00	0	23	X	X	X	X	X
21:00	0	23	X	X	X	X	X
22:00	0	23	X	X	X	X	X
23:00	0	22	X	X	X	X	X

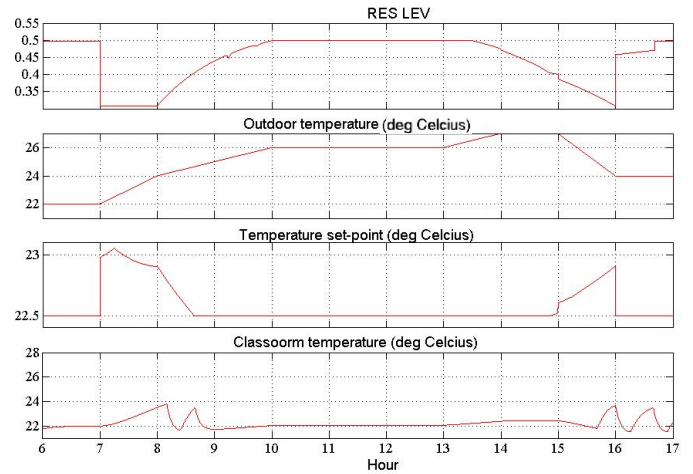


Fig. 10 Profiles of RES\_LEV, outdoor temperature, temperature set-point, classroom temperature of classroom-1.

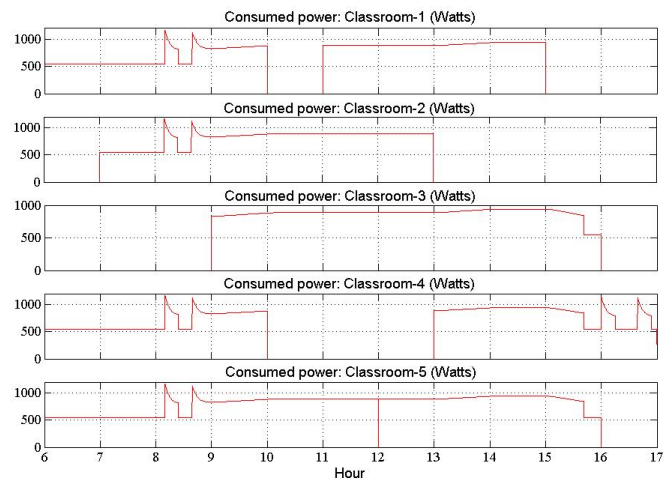


Fig. 11 Profiles of consumed power of classroom-1 to classroom-5.

TABLE V  
COMPARISON RESULTS OF PERFORMANCE INDEX

Method	en_lev	cf_lev	pi	
Fixed temperature set-point	21 °C	0.0039	0.8480	0.8519
	22 °C	0.0498	0.9124	0.9622
	23 °C	0.1475	0.8276	0.9751
	24 °C	0.4317	0.3541	0.7858
	25 °C	0.6358	0.0077	0.6435
Proposed system	0.0989	0.8913	0.9902	

To measure the effectiveness of the proposed system in the optimization of the electricity cost and the comfort level, we define the performance index ( $pi$ ) as follows:

$$pi = en\_lev + cf\_lev \quad (1)$$

$$en\_lev = 1 - \sum_h (c - p) / \beta \quad (2)$$

$$cf\_lev = 1 - \sum_h |st - rt| / \gamma \quad (3)$$

where  $en\_lev$  and  $cf\_lev$  represent the level of electricity cost and the temperature comfort respectively,  $c$  and  $p$  are consumed power by the loads and the PV power respectively,

$st$  and  $rt$  are the reference temperature and the classroom temperature respectively,  $\beta$  and  $\gamma$  are the constants for normalization, and  $h$  represents the hour.

In the simulation, we compare our proposed system, i.e. varying the temperature set-point, with the fixed temperature set-point. The comparison results are given in Table 5. It is clearly shown that the proposed method provides the highest value of the performance index ( $pi$ ). It means that our proposed system achieves the highest performance among the other methods (fixed temperature set-point). The table suggests that our proposed system achieves the high index of the temperature level. It conforms with the idea of the proposed algorithm that determining the temperature set-point according to the availability of power from the PV and the outdoor temperature.

In addition, we test our proposed MAS on the embedded system, especially dealing with the execution time, the implementation cost, and the communication interface. The embedded platform is similar to our previous work [16], i.e. using the low cost WeMos module [17]. The main algorithm of each agent is implemented on the WeMos module, which is communicated with other agents via the WiFi communication. From the experiments, the execution time of the FLC is 13 ms and the transfer time between each agent is 332 ms. The results show that our proposed method is suitable for the real-time implementation, in which the update time of building energy management system is usually on hourly basis.

#### IV. CONCLUSION

The MAS is proposed to manage the energy in the classrooms by varying the temperature set-point according to the PV power and the outdoor temperature. The FLC is adopted in the agents to find the optimal temperature set-point. The performance index representing the measurement of the level of electricity saving cost and the user comfortable level is developed which is used to compare the proposed system with the fixed temperature set-point. Using the developed performance index, the proposed system achieves the highest value of 0.9902. Further, the possible implementation in the real-time system is verified by a small embedded platform and shows the promising results, in terms of the fast execution time, i.e. less than one minute, and the low cost implementation of the embedded system.

In future, the system will be extended to cope with more complex building. The advanced algorithms will be adopted accordingly. Further the system will be implemented in the hardware prototype.

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