IEEE ROBIO
Sanya, China  December 27-31, 2021

The 2021 IEEE International Conference on
Robotics and Biomimetics
Welcome Message

Welcome to IEEE-ROBIO 2021, a.k.a. the 2021 IEEE International Conference on Robotics and Biomimetics. IEEE-ROBIO 2021 will be held December 27-31, 2021, at the Four Points by Sheraton Hainan, Sanya, China. Known for its original historical villages and contemporary luxury resort hotels, the City of Sanya has been among the most popular tourist destinations in China and worldwide. Its warm weather in winter months has attracted visitors worldwide. IEEE-ROBIO, an established and vibrant international conference, has been held annually since 2004 and has gained increasing international prominence in the field of Robotics and Biomimetics. Due to the COVID-19 Pandemic, IEEE-ROBIO 2020 and 2021 will be combined, and held jointly as a hybrid conference.

The theme of IEEE-ROBIO 2021, “Robotics and Biomimetics Meeting Society’s Grand Challenges”, reflects fast-growing interests and research effort in development and applications to fill the unmet needs, and their potential impact on people’s wellbeing and society. We are pleased to bring you the 2021 conference as a platform where a wide range of scientific topics is exchanged among researchers from different countries.

IEEE-ROBIO 2021 received a total of 398 paper submissions from 12 countries and regions. Upon a careful review process, 332 or 83% of the papers submitted were accepted into the technical program. Of the submitted papers, the top five topics are robot control, bio-inspired robotics, soft-material robots, manipulation, and robot learning. Countries and regions with the most paper submissions (in descending order) are China, Japan, Germany, Hong Kong, Great Britain, and the United States. The five-day conference program of IEEE ROBIO 2021 includes 3 plenary talks and 5 keynote speeches by leading researchers in robotics and biomimetics. The accepted papers of IEEE-ROBIO 2021 are organized into 46 oral sessions and three poster sessions.

IEEE-ROBIO 2021 is a result of a collective effort of many organizations and individuals. Without their support, dedication, and contribution, IEEE-ROBIO 2021 would not have been possible. First, our heartfelt appreciation goes to our sponsors, IEEE Robotics and Automation Society, Shenzhen Academy of Robotics, Chiba Institute of Technology, Nankai University, Shenyang Institute of Automation, CAS, Texas State University, Northeastern University, and NOKOV Co. Ltd. Secondly, we would like to express our gratitude for the tireless effort and work by the members of the IEEE-ROIBO 2021 Organizing Committee in their respective roles and capacities. Third, we would like to thank the members of the IEEE-ROBIO 2021 Technical Program Committee for their hard work which is the most critical in ensuring a fair and careful review process, and an inspiring technical program. Last but not least, we owe the success of this conference to all the authors of the papers submitted, and to the presenters who travel to present their works at the conference. IEEE-ROBIO 2021 is certainly your conference to enjoy and celebrate.

On behalf of the Organizing Committee of IEEE-ROBIO 2021, we welcome you to Sanya and to IEEE-ROBIO 2021, and wish you a great conference and an enjoyable and healthy stay in this fantastic city!

Zhidong Wang, General Chair
Chiba Institute of Technology

Jianda Han, Program Chair
Nankai University
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ROBIO 2021 Sponsors

We acknowledge the support of the following Sponsors to the 2021 IEEE International Conference on Robotics and Biomimetics (IEEE-ROBIO 2021).
GENERAL INFORMATION

Conference Date and Venue

Date: December 27-31, 2021
Venue: Four Points by Sheraton Hainan, Sanya
       No. 78 Sanya Bay Road, Sanya 572000 China

Registration Desk

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Conference Events

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Official Language

The official language of the conference is English.
All presentations, including discussions and paper submissions, shall be made in English.

Conference Attire

Casual attire is generally recommended for the Welcome and Farewell Receptions while a business suit or a white shirt with a neck-tie at all technical sessions and at the Conference Banquet.

Presentation Specifications

In each oral presentation room, one projector will be available. A laptop will be provided at each meeting room. The presenters should prepare Power Point Slides to facilitate their presentations. All onsite speakers in oral sessions should copy your ppt to the meeting room laptop and test it at least 15min before the session starts. The slides and the presentations must be in English. Please test the slides before session start to avoid potential format problems caused by different software versions. All online speakers in oral sessions must send their pre-recorded videos to t.sq.mgt@gmail.com by December 20, 2021. Speakers are required to join the live Q&A session via Tencent Conference.

Duration for each category of oral presentation is listed below:

- Plenary Lectures are scheduled for 60 minutes (including Q&A) each.
- Keynote Lectures are schedule for 40 minutes (including Q&A) each.
- Regular Sessions are schedule for 12 minutes with 3 min Q&A each.
Poster Specifications

Poster session represents an effective and valuable means for authors to present their research results. It offers an opportunity of meeting with interested attendees for in-depth scientific and technical discussions, and establishing new collaborations. Therefore, it is important that you display your results clearly to attract people who have an interest in your team’s research work.

Your poster should cover the KEY POINTS of your paper, which include but not limited to background, methods, results and conclusion. Make your poster as self-explanatory as possible. This will save your time for discussions and questions with fellow researchers.

POSTER DIMENSIONS

- Your poster SHOULD have the following dimensions:
- **Poster Size: 90cm (W) x 120cm (H).**
- Please note that printing out your submitted full paper in A4 size format is NOT acceptable as a poster.

POSTER CONTENT

- **Title:** The title of your poster should appear at the top with lettering of at least 42 pt font size). Below the title, place the names of authors and their affiliations.

- **Text:** Text should be readable from five feet away. Use a minimum font size of 17 pt. Keep the text brief. Try to use text to introduce the study, explain visuals and direct viewers’ attention to significant data trends and relationships portrayed in the visuals, state and explain the interpretations that follow from the data. It is also a good idea to put future research plans or questions for discussion with viewers in your text.

- **Figures:** Each figure should have a brief title. Figures should be numbered consecutively according to the order in which they are first mentioned in the text. Try to use color figures rather than only black and white text to make your poster attractive and highlight the important technical content of your paper. Make sure that the text and the visuals are integrated.
Conference Awards

Best Conference Paper Award
Any paper with original research results can be considered for the Best Conference Paper Award, provided that the research results presented have not been presented anywhere else in the world at the time of paper submission.

Best Student Paper Award
Any original research work can be considered for the Best Student Paper Award, provided that the first author is a student and primary developer of the ideas contained in the paper.

Best Paper in Biomimetics Award
Any paper with original research results in Biomimetics area can be considered for the Best Conference Paper in Biomimetics Award, provided that the research results presented have not been presented anywhere else in the world at the time of paper submission.

T.J. Tran Best Paper in Robotics Award
Any paper with original research results in Robotics area can be considered for the Best Conference Paper Award, provided that the research results presented have not been presented anywhere else in the world at the time of abstract submission.
Floor Map

1/F-(Plenary Talks, Keynote Talks, Oral Sessions, Poster Sessions, Coffee Breaks and Conference Banquet)

3/F-(Oral Sessions)
Four Points by Sheraton Hainan, Sanya is located at Sanya Bay, just 1 min away from beach. The convenient location will offer easy access to all the local sightseeing and shopping malls, enjoy local food and night life. Sanya Phoenix Airport are just 15 minutes away.

- 5 min from Downtown
- (NO. 8, 15, 25, 26, 30, 34, 57 bus)
- 10 min from Sanya Train Station (NO. 15 bus)
- 15 min from Phoenix Airport (NO. 8, 27, 34 bus)
- 20 min from Dadong Sea (NO. 8, 25, 15, 34 bus)
- 30 min from YalongBay (NO. 15, 25, 27 bus)
- 40 min from HaitangBay (NO. 34 bus)
- 40 min from TianyaHaijiao (NO. 25, 26, 30 bus)
Dexterous Manipulation of Objects

Aude Billard

Professor
EPFL, Switzerland

Abstract:
Dexterous manipulation of objects is robotics’ 21st century primary goal. It envisions robots capable of sorting objects and packaging them, of chopping vegetables and folding clothes, and this, at high speed. Traditional control approaches are insufficient for lack of accurate models of objects and contact dynamics. Robotics leverages, hence, the immense progress in machine learning to encapsulate models of uncertainty and to support further advances on adaptive and robust control. This talk will provide an overview of efforts in my group to take inspiration in the way humans acquire this exquisite dexterity at manipulating objects. We move away from picking up objects with a gripper and show how all 16 degrees of freedom humanoid hand can be used at last for all their worth, such as to hold several objects in the same hand, or to explore the inside of objects. I will present new approach using machine learning in conjunction with control to enable robust manipulation in the face of poor models of the robot’s dynamics and of the tissues or inertia of the objects manipulated. I will show examples of application of this work to rotate in-the-fingers a glasses containing liquid and to cut tissues.

Biography:
Aude Billard is full professor and head of the LASA laboratory at the School of Engineering at the Swiss Institute of Technology Lausanne (EPFL). She was a faculty member at the University of Southern California, prior to joining EPFL in 2003. She holds a B.Sc and M.Sc. in Physics from EPFL (1995) and a Ph.D. in Artificial Intelligence (1998) from the University of Edinburgh. She was the recipient of the Intel Corporation Teaching award, the Swiss National Science Foundation career award in 2002, the Outstanding Young Person in Science and Innovation from the Swiss Chamber of Commerce and the IEEE-RAS Best Reviewer Award. Her research spans the fields of machine learning and robotics with a particular emphasis on learning from sparse data and performing fast and robust retrieval. Her work finds application to robotics, human-robot / human-computer interaction and computational neuroscience. This research received best paper awards from IEEE T-RO, RSS, ICRA, IROS, Humanoids and ROMAN and was featured in premier venues (BBC, IEEE Spectrum, Wired).
MicroHand: A Surgical Robot System for Minimally Invasive Abdominal Surgery

Shuxin Wang
Professor and Vice President
Tianjin University, China

Abstract:
The MicroHand robot system is a minimally invasive abdominal surgery system independently developed by Tianjin University. This presentation describes the design principle of the MicroHand system, and analyzes the kinematic characteristics and dynamic behaviors of the system. The system adopts the design of wire-driven surgical instrument with a decoupled end, which enhances the flexibility of surgeons' operation. A folding RCM manipulator with light-weight structure is designed. The system has performed a large number of animal experiments and multi-center clinical trials. The MicroHand system is the first surgical robot system for minimally invasive abdominal surgery approved by National Medical Product Administration of China. Supported by the 5G technology, the MicroHand system has successfully carried out 50 remote clinical trial operations.

Biography:
Professor Shuxin Wang is the Vice President of Tianjin University (TJU), a Yangtze River Scholar of the Ministry of Education, and the winner of National Science Fund for Distinguished Young Scholars of China. He has been awarded twice the National Science and Technology Award of China. He is the director of the Medical Robotics Joint Research Center co-established by Tianjin University and Wego™ Group, and the director of Ministry of Education Key Laboratory of “Mechanism Theory and Equipment Design”. He is a member of the Technical Committee for Multibody Dynamics in International Federation for the Promotion of Mechanism and Machine Science (IFToMM), and the associate editor of IEEE Transactions on Medical Robotics and Bionics. His research interests are surgical robotics, underwater glider, and flexible mechanism systems. He is the author or co-author of over 160 academic papers and has over 80 authorized patents. He and his team are well known for the development of the “MicroHand” robot, which is the first minimally invasive surgical robotic system that has conducted human clinical trials in China. He and his team have also developed a series of Underwater Gliders (named Petrel), which set a world record by diving to 10,619 meters.
Dynamic Organization of Global Cell Assembly for Cognition

Chengyu Li

Professor
Institute of Neuroscience
Center for Excellence in Brain Science and Intelligence Technology
CAS, China

Abstract:
My lab is working on neural mechanism underlying cognition, with an aim to advance AI. We are particularly interested in working memory (WM), which maintains information during a delay period by internally generated neuronal activity. We examined the dynamic organization of global cell-assembly activity that encodes WM information via cross-regional sequential spiking. Multiple Neuropixels-probe single-neuron recordings were made from over 60 brain regions in head-fixed mice performing an olfactory WM task. We found that neurons encoded WM during the delay period predominantly by transient activity that formed cross-region sequential waves, with strong constraint set with brain structure. Functional coupling and cross-region loop analysis also revealed strong links between memory-encoding activity waves with brain-wide functional connection. Applying the dynamic rules observed from the mouse brain in designing rate-based and spiking neural networks led to the observation of travelling-wave like spike-train dynamics, better performance in solving of a delayed paired association task, and improved incremental learning in a 10-class handwritten-digit classification task. We are working on recording brain-wide neuronal activity from other cognitive tasks in mice as well as from awake behaving monkeys. Thus, our results uncovered structurally and functionally organized global cell-assembly dynamics mediating WM maintenance and underscored the importance of incorporating principles of neuronal dynamics in designing better AI.

Biography:
LI Chengyu obtained his B.S. degree in Department of Physiology and Biophysics, School of Biological Sciences, Peking University, 1995-1999. Studying between 1999 and 2004, Chengyu Li obtained his PhD degree in Institute of Neuroscience, Chinese Academic of Sciences, Shanghai. Between 2004 and 2009, Chengyu Li studied as Postdoctoral Fellow in Department of Molecular & Cell Biology, Helen Wills Institute of Neuroscience, University of California, Berkeley, CA, USA. His main interests are in the functional circuitry of behavior, including social behavior, working memory, and long-term memory.
Keynote Talks

Keynote Talk I: Tuesday, December 28, 2021  09:00-09:40

Session Chair: Lianqing Liu, Shenyang Institute of Automation, CAS;
Zhidong Wang, Chiba Institute of Technology

Nonlinear Control of Cable-Suspended Flight Transportation Systems

Yongchun Fang
Professor
Nankai University, China

Abstract:
Cable-suspended transportation is an important way of transferring goods and materials by rotorcrafts in complex and hazardous environments, where external disturbances, system uncertainties, as well as the “twofold” underactuated characteristics, bring great challenges to realize safe and smooth deliveries. This talk discusses the latest research results on the dynamics analysis, motion planning, and nonlinear control of the quadrotor transportation systems. Specifically, based on Lagrangian mechanics, a precise model is set up for the “twofold” underactuated aerial transportation system. Then, a time-optimal motion planning technique is proposed to generate a minimum-time trajectory in consideration of state and control constraints. Finally, some nonlinear control algorithms are designed to achieve asymptotic stability, whose performance is verified by various experimental results.

Biography:
Yongchun Fang received the B.S. degree in electrical engineering and the M.S. degree in control theory and application, both from Zhejiang University, P. R. China, in 1996 and 1999, respectively, and the Ph.D. degree of electrical engineering from Clemson University in 2002. From 2002 to 2003, Dr. Fang was a postdoctoral research fellow at the Mechanical and Aerospace Engineering Department, Cornell University. Since 2003, Dr. Fang has been a professor at the Institute of Robotics and Automatic Information System, Nankai University, Tianjin, P. R. China, and he is also a Yangtze River Distinguished Professor of the Chinese Minister of Education. Dr. Fang’s research interests include underactuated systems control, visual servoing, AFM-based nanomanipulation, and so on. Dr. Fang is a recipient of the China National Funds for Distinguished Young Scientists, and he won the First Prize of Wu Wenjun Natural Science of Artificial Intelligence in 2017.
Towards Facilitating Safe and Secure Decommissioning of the Fukushima Daiichi Nuclear Power Station by Remotely Operated Robotics

Kuniaki Kawabata

Professor
Collaborative Laboratories for Advanced Decommissioning Science (CLADS), Japan Atomic Energy Agency (JAEA), Japan

Abstract:
After the accident in 2011, remotely operated robots have been used to decommissioning of the Fukushima Daiichi Nuclear Power Station of the Tokyo Electric Power Company Holdings Inc.. The decommissioning period is estimated for 30 or 40 years and remotely operated robotics is providing essential solutions to ensure safe and secure task execution. In this talk, we will introduce lessons learned from past remote task executions. In addition, R&D activities of our group on the technologies committing to performance evaluation for the systems and improvement of operator proficiency/spatial awareness in order to maintain safe and secure decommissioning operations will be introduced.

Biography:
Dr. Kawabata received Ph.D from Hosei University and was a Special Postdoctoral Researcher, The Institute of Physical and Chemical Research (RIKEN) in 1997. Then he was Research Scientist then Unit Leader at RIKEN until joining Japan Atomic Energy Agency in 2015 where he became Principal Investigator at the CLADS, JAEA in 2017. He is a senior member of IEEE and a member of JSME, SICE, RSJ and AESJ.
Interdisciplinary Robot Research and Its Management

Kanako Harada

Professor
The University of Tokyo, Japan

Abstract:
In the applied research of robots, research collaboration with future robot users is essential. We have been collaborating with surgeons for years to develop autonomous surgical robots; however, the needs of surgeons are often provided in a qualitative manner (for example, “smaller is better”, “the target tissues are very soft”, etc.), and additional needs are given during the evaluation of a prototype, and thus prototyping must be repeated many times. In the research domain of surgical robotics, such repeated prototyping has made it difficult to advance the robotic technologies themselves. In the ImPACT project “Bionic Humanoids Propelling New Industrial Revolution”, we developed elaborate human model equipped with sensors named as Bionic Humanoid, as a means to quantitatively understand the needs of surgeons and to quantitatively evaluate the performance of a prototype. As a concrete example, we developed a new surgical robot named SmartArm in a short period of time using the Bionic Humanoid and also evaluated the SmartArm’s performance quantitatively using the Bionic Humanoid. The project succeeded in demonstrating the importance of project management, and the success led to the launch of a new Moonshot project "Co-evolution of Human and AI-Robots to Expand Science Frontiers" in December 2020. The Moonshot is a national flagship initiative, and this project aims at one of the Moonshot’s goals, namely, "By 2050, development of an automated AI robot system that aims to discover impactful scientific principles and solutions, by thinking and acting in the field of natural science”. We will develop AI-robot scientists by interdisciplinary project management. Our project includes not only engineering researchers who will study the next-generation AI and robots, but also scientists who will be the future users of the AI-robots, and mathematical researchers who will make academic contributions to the applied research. In this talk, I will introduce the results of the ImPACT project and the plan of the Moonshot project.

Biography:
Kanako Harada is Associate Professor of the Center for Disease Biology and Integrative Medicine (CDBIM), Graduate School of Medicine, The University of Tokyo, Japan, and she also belongs to the Department of Bioengineering and the Department of Mechanical Engineering, Graduate School of Engineering. She serves as a Project Manager for one of the national flagship projects “Moonshot” by the Cabinet Office. She obtained her M.Sc. in Engineering from The University of Tokyo in 2001, and her Ph.D. in Engineering from Waseda University in 2007. She worked for Hitachi Ltd., Japan Association for the Advancement of Medical Equipment, and Scuola Superiore Sant’Anna, Italy, before joining The University of Tokyo. She also served as a Program Manager for the ImPACT program of the Cabinet Office (2016 - 2019). Her research interests include surgical robotic systems, automation of robots for medical applications, skills assessment, patient models, virtual-reality simulators, and regulatory science.
Biomimetic on Gecko Locomotion: From Biology Studies to Engineering Applications

Zhendong Dai
Professor
Nanjing University of Aeronautics and Astronautics, China

Abstract:
[Geckos have been studied for many years for their excellent moving abilities on various substrates, including any inclines, even ceilings, and various rough surfaces. Here we report our studies on the gecko adhesive mechanism, attaching and detaching dynamics, locomotion behaviors on anti-adhesive substrate and confined space, bio-inspired adhesive materials and gecko-inspired robot for micro-gravity condition. We have obtained following results: 1) The contact/tribo-electrifiction is a mechanism more than Van der Waals force for gecko adhesion, we designed an experiment and measured the results showed the evidence of influence of contact/tribo-electrifiction on adhesion. 2) Gecko smartly uses technique of adducting and abducting to make attachment and detachment, this behavior inspired us to design a new pad for gecko-mimicking robot, instead of peeling from substrate. 3) Geckos developed positive and active synergy methods to overcome the difficult to move on anti-adhesive substrate. 4) We have developed bio-inspired adhesive materials and tested they performance for gecko mimicking robot. 5) Then we developed gecko-inspired soft adaptive robot hand and robot for several possible applications.]

Biography:
Dr. Zhendong Dai, Professor, director and founder of the Institute of Bio-inspired Structure and Surface Engineering (IBSS) at Nanjing University of Aeronautics and Astronautics (NUAA), fellow of International Society of Bionic Engineering. His research interesting include tribo-irreversible thermodynamics, biomimetic on gecko locomotion, bio-inspired lightweight structure, brain stimulation of animal moving. He set up research methods and developed facilities to reveal the role of behavior and measure the reaction forces of gecko locomotion, design the micro-structures of adhesive pads and developed the manufacture system, designed gecko mimicking robots for on-orbit applications and confined space inspection. He has published more than 400 papers and patented over 60 inventions. He founded Industry Institute of Bionic Technology, and transferred several technology into products, including 6 dimensional force sensors and force-feed back controlling technology, adhesive materials and soft adaptive robot hands, wall-cleaning robots.
Trends and Challenges of Unmanned Systems Research

Ben M. Chen

Professor
Department of Mechanical and Automation Engineering
Chinese University of Hong Kong
Hong Kong, China

Abstract:
In this talk, we are to highlight some trends and challenges in the development of autonomous unmanned systems and their integration with AI techniques for real industrial applications. Topics covered are some unconventional unmanned systems hardware platforms, issues on dynamics modeling and control, motion planning, task planning, positioning, localizations, and the integration of unmanned systems with AI techniques for industrial applications.

Biography:
Ben M. Chen is currently a Professor of Mechanical and Automation Engineering at the Chinese University of Hong Kong (CUHK). He was a Provost's Chair Professor in the Department of Electrical and Computer Engineering at the National University of Singapore, before joining CUHK in 2018. He was an Assistant Professor in the Department of Electrical Engineering at the State University of New York at Stony Brook, in 1992–1993. His current research interests are in unmanned systems, robust control and control applications.

Dr. Chen is an IEEE Fellow, CAA Fellow, and Fellow of Academy of Engineering, Singapore. He has authored/co-authored about 500 journal and conference articles, and a dozen research monographs in control theory and applications, unmanned systems and financial market modeling. He had served on the editorial boards of a dozen international journals including Automatica and IEEE Transactions on Automatic Control. He currently serves as an Editor-in-Chief of Unmanned Systems. Dr. Chen has received a number of research awards. His research team has actively participated in international UAV competitions and won many championships in the contests.
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<thead>
<tr>
<th>Time</th>
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<td>14:00-18:00</td>
<td>Registration</td>
<td>Hotel Lobby, 1/F</td>
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<tr>
<td>18:00-20:00</td>
<td>Welcome Reception at Eatery, 2/F (for all registered attendees)</td>
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### December 28 (Tuesday)

**Phoenix Ballroom, 1/F**

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<tr>
<th>Time</th>
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<td>08:50-09:00</td>
<td><strong>Opening Ceremony</strong></td>
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<tr>
<td>09:00-09:40</td>
<td><strong>TuKL1 - Keynote Talk I:</strong> Yongchun Fang, Nankai University, China</td>
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<tr>
<td></td>
<td><em>Nonlinear Control of Cable-Suspended Flight Transportation Systems</em></td>
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<td>(Chairs: Lianqing Liu, Zhidong Wang)</td>
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<td>09:40-10:20</td>
<td><strong>TuKL2 - Keynote Talk II:</strong> Kuniaki Kawabata, Japan Atomic Energy Agency, Japan</td>
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<td><em>Towards Facilitating Safe and Secure Decommissioning of</em></td>
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<td><em>the Fukushima Daiichi Nuclear Power Station by Remotely Operated Robotics</em></td>
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<td>(Chairs: Ningbo Yu, Heping Chen)</td>
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<td>10:20-10:45</td>
<td><strong>Coffee Break</strong></td>
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<td>10:45-12:00</td>
<td><strong>TuA1-Manipulation I:</strong></td>
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<td>12:00-13:00</td>
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<td>13:00-14:15</td>
<td><strong>TuB1-Surgical Robots I:</strong></td>
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<td>14:15-14:35</td>
<td><strong>Coffee Break</strong></td>
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<td>14:35-15:50</td>
<td><strong>TuC1-Manipulation II:</strong></td>
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<td>16:00-17:00</td>
<td><strong>TuPL1 - Plenary Talk I:</strong> Aude Billard, EPFL, Switzerland</td>
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<td><em>Dexterous Manipulation of Objects</em></td>
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<td>(Chairs: Hong Zhang, Fei Chen)</td>
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<td>09:00-10:00</td>
<td><strong>WePL2 - Plenary Talk II:</strong> Shuxin Wang, Tianjin University, China</td>
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<td><em>MicroHand: A Surgical Robot System for Minimally Invasive Abdominal Surgery</em> (Chairs: Jianda Han, Lianqing Liu)</td>
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<td>10:00-10:40</td>
<td><strong>WeKN3 - Keynote Talk III:</strong> Kanako Harada, University of Tokyo, Japan</td>
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<td><em>Interdisciplinary Robot Research and Its Management</em> (Chairs: Fei Wang, Zhidong Wang)</td>
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<td>10:40-11:00</td>
<td>Coffee Break</td>
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<td><strong>WeA1-Planning &amp; Control I:</strong> (ID: 192, 299, 316, 322, 113, 367)</td>
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<td><strong>WeA2-Underwater Robots:</strong> (ID: 202, 50, 61, 185, 253, 95)</td>
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<td><strong>WeA3-EMG:</strong> (ID: 347, 234, 318, 111, 251, 317)</td>
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<td><strong>WeA4-SLAM:</strong> (ID: 37, 257, 303, 285, 227, 370)</td>
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<td><strong>WeA5-Soft Robots:</strong> (ID: 385, 365, 218, 250, 271, 89)</td>
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<td>15:30-17:15</td>
<td><strong>WeC2-Rehabilitation &amp; Assistive Robots:</strong> (ID: 184, 336, 288, 81, 359)</td>
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<td><strong>WeC3-Robotic Exoskeletons:</strong> (ID: 302, 335, 368, 75, 142)</td>
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<td><strong>WeC4-System Design &amp; Optimization II:</strong> (ID: 354, 374, 377, 382, 277)</td>
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<td><strong>WeC5-Dynamics &amp; Control II:</strong> (ID: 373, 85, 178, 229, 356)</td>
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<td>18:00-20:00</td>
<td>Conference Banquet and Award Presentation (for all registered attendees)</td>
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<td>09:00-10:00</td>
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<td>10:00-11:20</td>
<td>Plenary Talk III: Chengyu Li, Institute of Neuroscience, CAS, China</td>
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<td>Dynamic Organization of Global Cell Assembly for Cognition</td>
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<td>10:00-10:40</td>
<td>ThPL3 - Plenary Talk III: Chengyu Li, Institute of Neuroscience, CAS, China</td>
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<td>Biomimetic on Gecko Locomotion: From Biology Studies to Engineering Applications</td>
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<tr>
<td>10:40-11:20</td>
<td>ThPo5-Poster Session V: Trends and Challenges of Unmanned Systems Research</td>
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<td>11:20-11:40</td>
<td>Coffee Break</td>
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<tr>
<td>14:00-15:30</td>
<td>ThA4 - Robot Vision I:主要从事机器人视觉技术研究</td>
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<td>15:30-15:50</td>
<td>Coffee Break</td>
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<td>15:50-17:05</td>
<td>ThPo6-Poster Session VI:</td>
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<td>Trends and Challenges of Unmanned Systems Research</td>
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<td>Lunch at Eatery, 2/F</td>
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<tr>
<td>17:00-18:00</td>
<td>Farewell Dinner</td>
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Technical Sessions

Tuesday, December 28
TuPo1: Poster Session I

Room: Foyer, 1/F, 10:20-10:45, Tuesday, December 28, 2021

TuPo1(1) 10:20-10:45
Adaptive Step Puncture Strategy Based on Online Identification of Tissue Shore Hardness
Li Changjie, Yu Chuanyou, Zhang Lefeng, Ban Guang, Fan Yilun, Yubin Lu, Zhao Jie, Member, IEEE
Harbin Institute of Technology, Harbin, Heilongjiang, China

- Design of puncture end tool
- Puncture strategy proposal process
- Following experiment

TuPo1(2) 10:20-10:45
Critical Information Selection for Affective Brain-Computer Interfaces Based on Brain Function Networks
Jinying Bi and Xin Yan
College of Information Science and Engineering, Northeastern University, China
Fei Wang and Jingyu Ping
Faculty of Robot Science and Engineering, Northeastern University, China

- Design to find the best threshold for constructing brain function networks.
- Design to obtain the best frequency bands and channels combination for emotion recognition.
- Verify that the critical information for emotion recognition is reasonable.
- Reduce the amount of calculations and simplify the electrode device for emotion recognition.

TuPo1(3) 10:20-10:45
Knee Trajectory Modulation for Impact Reducing of Lower Limb Exoskeletons
Long Zhang1, Guangkui Song1, Chuabin Zou1, Hong Cheng2, Bao Huagong1, and Jing Qua1
1School of Automation and Engineering, UESTC, Chengdu, China
2School of Mechanical and Electrical Engineering, Zhejiang University of Technology, China

- The shock-absorbing model (SAM) based on the kinematic spring-damping system has been proposed for walking assistance simulations.
- Enables reduction of Ground Reaction Force (GRF) without bulky mechanical structures.
- The proposed approach has been verified by the AIDER exoskeleton.

TuPo1(4) 10:20-10:45
Grasping Force Control for a Soft Finger with SMA Actuator based on Inverse Models and Lag Compensations
Haibin Yin and Jian Yang and Jiaoyuan Wang
School of Mechanical and Electrical Engineering, Zhejiang University of Technology, China

- The research object is the grip control of soft fingers driven by SMA.
- Control methods include model prediction, lag compensation, PID and PIP-P3.
- The experiment includes step instruction experiment and sine instruction experiment.
- The control performance of predictive controller based on mathematic model is better.

TuPo1(5) 10:20-10:45
A motion assignment strategy based on macro-micro robotic system for enhancement of kinematic performance
Yachua Zhou1,2, Qin-Yin Chen1,2, Renfang Zhu3, Yu Yant1,2, Guiliu Yang, Weijun Wang, Yaonan Li
1University of Chinese Academy of Sciences, 2Beijing Institute of Materials Technology and Engineering, 3School of Mechanical and Electrical Engineering, Zhejiang University of Technology, China

- Kinematics analysis of the macro and the micro;
- Construction of the numerical workspace of the micro as a search set;
- Traaversal of the search set and select the optimum while considering the smoothness of the trajectory.

TuPo1(6) 10:20-10:45
MEMS Accelerometer Stability and Temperature Compensation for Long Term Structure Surveillance System
Yanqiu Rong, Zongkai Jia, Guang Luo, Congying Ma, Guangyi MIA, and Jianyue Zhang

A novel filter for the multi-sensor monitoring system is designed. The multi-channel algorithm is designed by adding many monitoring data. Temperature compensation system is designed. Temperature compensation model with a polynomial equation is proposed. Experimental results show the difference between the heating curve and the cooling curve, a method for selecting the heating and cooling according to the readings of the temperature sensor is proposed.

- MEMS sensor with robust structure
- Filter logic for short-term indoor fluctuation

Figure (a) driving force, (b) grasping force and (c) kinematics
TuPo1: Poster Session I (cont.)

Room: Foyer, 1/F, 10:20-10:45, Tuesday, December 28, 2021

TuPo1.2(7) 10:20–10:45

Compatible Structure Design of a Lower Limb Exoskeleton for Gait Assist
Dong Zhao, Xia Zhang and Hao Fu
College of Mechatronics and Automobile Engineering, Chongqing Jiadong University, China

- A novel human-exoskeleton compatible configuration scheme obtained through configuration optimization
- Exoskeleton ankle motion area compatibility with the human ankle motion area verified through simulation
- Comparison of the compatibility of human-exoskeleton motion with the compatibility scheme and other 7 types of non-compatibility schemes
- The deviation of the human-exoskeleton joint angular displacement under the compatibility scheme is the smallest

TuPo1.2(8) 10:20–10:45

Dynamic Modeling and Compliant Control for a Lower Extremity Exoskeleton Robot Based on BP Neural Network
Zhifei Li, Yan Zeng, Di Zhu and Shuang Zhang
Beihang University

Abstract: In order to realize the active control of the exoskeleton, a 7-DOF lower extremity exoskeleton robot with motion boundary force control was designed. A dynamic modeling method of the robot was proposed in this paper. Finally, the dynamic model of the robot was established and a control method was designed. The simulation results showed that the dynamic model of the robot is reliable and the control method is feasible. The experiment results showed that the exoskeleton robot could realize the motion control of the human leg and the experiment results were in line with the simulation results.

TuPo1.2(9) 10:20–10:45

Design of a Passive Exoskeleton Chair with an Auxiliary Support Mechanism for Assembly Tasks
Yifei Han, Ying Liu, and Wuxing Zhang

TuPo1.2(10) 10:20–10:45

A way for regulating branch tip fusion behavior based on Turing mechanism
Man Huang and Yutian Li

Institute of Robotics and Automation Information Systems, Nankai University, China

- A regulation method of branch tip fusion behavior based on the Turing mechanism of branch tip fusion behavior is established.
- The regulation method is realized by regulating the key model parameters to adjust Turing wavelength.
- By decreasing the parameter $\rho_1$ (mismatch rate of activator by different branches) or increasing $\rho_2$ (mismatch rate of inhibitor by differentiated cells), the fusion behavior of branch tips could be promoted.

TuPo1.2(11) 10:20–10:45

The Soft Continuum Robot Based on Large Deflection Theorem
Mannrong Wang and Wenbiao Wang
College of Mechanical Engineering, Zhejiang University of Technology, China
Guanjun Bao
College of Mechanical Engineering, Zhejiang University of Technology, China

- A new soft continuum robot dynamic model modeling idea.
- The pneumatic soft continuum robot is regarded as a variable-stiffness beam.
- The soft continuous robot pressure model is used to solve the deflection curve equation.

TuPo1.2(12) 10:20–10:45

Towards Enhanced Social Well-being for the Disabled Using Humanoid Robot with Eye Tracker
Xueyi Zhang1, Xinchao Wang1, Jiahao Fang2 and Zhenglong Sun1,2
1Shenzhen Institute of Artificial Intelligence and Robotics for Society, China
2ISEE, The Chinese University of Hong Kong, Shenzhen, China

- An intelligent system that can assist the disabled to play Chinese chess with other normal people without any physical movement by using a robot with a visual sensor.
- The system consists of three parts: visual recognition, eye tracking, and robotic manipulation.
- The system was able to complete the task in 13 out of 15 rounds
**TuPo1: Poster Session I (cont.)**

Room: Foyer, 1/F, 10:20-10:45, Tuesday, December 28, 2021

**TuPo1_3(13) 10:20-10:45**

**Multiple Tissue Sample Collection Device for MRI Guided Transrectal Prostate Biopsy: Preliminary Study**
Farshad Ampe, Jing Li, and Seung Yong Ko

MTSD collects and stores tissue samples, automatically, taken in a real-time MRI-Guided Prostate Biopsy. It uses two layers of paper to collect and trap the biopsy samples. These layers roll over a pair of pulleys which have been connected and synchronized with timing pulleys. The device can be actuated with a motor, or without a motor using already available backward motion of the biopsy gun.

**TuPo1_3(14) 10:20-10:45**

**An orthogonal calibration method for the multi-core fiber shape sensor**
Zhenxing Wang, Meng Liu, and Hao Liu
Shenyang Institute of Automation, China

1. The installation error analysis of multi-core fiber shape sensor
2. Proposed an orthogonal calibration method and operation specification
3. Derive the shape reconstruction algorithm based on installation parameters
4. Verify the calibration method by digital simulation and sensor experiments

**TuPo1_3(15) 10:20-10:45**

**Denosing of Pulse Wave Signal by Wavelet Packet Transform**
Yibin Lu, Min Li, Biteng Wu, Youyuan Tang, and Zijian Wei
School of Mechatronic Engineering and Automation, Shanghai University, China

1. A high sampling rate two-channel pulse wave signal measuring instrument based on AFE4490 and STM32H743IIT6 is designed
2. The noise analysis of two-channel pulse wave signal is carried out by frequency domain and wavelet packet transform
3. In this paper, the heart rate accuracy experiment and PPT value comparison experiment under different sampling rates were designed to verify the data accuracy of the dual-channel pulse wave measuring instrument

**TuPo1_3(16) 10:20-10:45**

**Structural Design and Analysis of Unpowered Exoskeleton for Lower Limb**

Zhenya He1,2, Siqi Chen1, Xianmin Zhang1, Guojian Huang1, Junming Wang2
1 Guangdong Provincial Key Laboratory of Precision Equipment and Manufacturing Technology, South China University of Technology, China
2 School of Electrical Engineering, Guangdong Mechanical & Electrical, China

1. An unpowered exoskeleton for lower limb was designed.
2. The load to the user and energy consumption while walking can be reduced simultaneously.
3. It has the advantage of light weight, simple structure, and good adjustability.

**TuPo1_3(17) 10:20-10:45**

**Feasibility Study of Stable Contact Force Control for Bone Milling**
Wenyuan Liang
College of Engineering, Peking University, China
National Research Center for Rehabilitation Technical Aids, China

1. The feasibility study is operated based on a 6-DOF medical robot.
2. The milling control algorithm is a hybrid position/force control algorithm.
3. The experiments of feasibility test include the milling on the flat surface and the complex surface with large curvature.
4. The experimental results show that the proposed control algorithm could maintain a stable milling force between the milling tool and the surface along the normal direction.

**TuPo1_3(18) 10:20-10:45**

**A soft actuator with integrated pneumatic source using electrically induced liquid-to-gas conversion**
Yao Xu, University of Chinese Academy of Sciences, Beijing, China
Ting Wang, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang, China
Zhidong Wang, Chiba Institute of Technology, Chiba, Japan

1. An electrochemical pump was designed based on a reversible proton exchange membrane fuel cell (RPEMFC). The electrochemical pump is robust to pose variations via the structural gas conversion.
2. The electrochemical pump is robust to pose variations via the structural design.
3. An electrochemical pump is designed for a low-voltage DC power (>3 V), and provides high performance in terms of deformation stroke and load capacity.

![Diagram](image-url)
Control and Collaboration of Self-Balancing Spherical Robots

Liyan Chen, Sheng Bi, George Zhang, Shujia Qin*, and Ning Xi
Shenzhen Academy of Robotics, China

• Restricted space environment (e.g. narrow tunnels, pipelines, and high obstructions) has detection challenges
• Omnidirectional spherical robot has the preferable characteristics of low power consumption, high stability, and high mobility
• This paper introduced a compact and flexible self-balancing spherical robot system with a motion controller based on a mix of existing design patterns

Prototype of the spherical robot
TuA1: Manipulation I

Session Chairs: Wenfu Xu and Yanding Qin

Room: Phoenix Ballroom, 1/F, 10:45-12:00, Tuesday, December 28, 2021

TuA1(1) 10:45–11:00

**Variable-Cross-Sectional Continuum Manipulator capable of grasping by whole-arm wrapping**

Zuan Li, Yixin Xie, Han yuan*, Wenfu Xu
School of Mechanical Engineering and Automation, Harbin Institute of Technology Shenzhen, China

- A Variable-Cross-Sectional Continuum Manipulator (VCSCM) was designed
- Realize wrapping and grasping objects through whole-arm operation.
- The kinematics model of continuum manipulator is established based on the assumption of Piecewise Constant Curvature.
- The space trajectory accuracy test and winding grasp experiment were carried out using a prototype.

TuA1(2) 10:00–11:15

**Adaptive Trajectory Tracking and Vibration Suppression Control for Flexible Space Manipulator**

Zeyuan Huang, Gang Chen, and Hong You
School of Automation, Beijing University of Posts and Telecommunications, China

- The dynamic model of non-planar flexible space manipulator is established
- The dynamic model is decomposed according to the time scale of movement response for better astigmatism
- A two-time scale controller with uncertain model parameters is designed for trajectory tracking and vibration suppression simultaneously

TuA1(3) 11:15–11:30

**Reachable range analysis and position control of the free-swinging joint for an underactuated space manipulator**

Yingzhuo Fu, Qingxuan Jia, Gang Chen, and Hanxiao Wang
School of Automation, Beijing University of Posts and Telecommunications, China

- Dynamic coupling model of a space manipulator with a free-swinging joint failure is established.
- The reachable range of the free-swinging joint is analyzed through considering the possible influential factors.
- A position control algorithm considering the controllability for the space manipulator is proposed.

TuA1(4) 11:30–11:45

**Distributed Force Synchronization for Networked Robotic Manipulators with Transmission Delays**

Zhang Xiaodong¹, Chao Ma², Tao Xiao¹ and Liziyi Hao
¹Beijing Institute of Spacecraft System Engineering, Beijing, China
²University of Science and Technology Beijing

The trajectory of the free-swinging joint and actuated joint
TuA2: Micro/Nano Robots
Session Chairs: Haibo Yu and Xiao Liang
Room: Nan Shan A, 3/F, 10:45-12:00, Tuesday, December 28, 2021

TuA2(1) 10:45–11:00
A Novel Micropipette Robot for Cell Manipulation Based on DEP and EOV
Shengjie Yang and King Wai Chiu Lai
Department of Biomedical Engineering, City University of Hong Kong, Hong Kong SAR, China

- Low-frequency and low-voltage electric field combine dielectrophoretic effect and electroosmotic vortex
- High directivity net force acts on the target cell
- Accurately guides the manipulation process by monitoring cell deformation

Experimental schematics of DEP and EOV

TuA2(2) 11:00–11:15
Robotic Visual and Electrical Guided Whole-Cell Patch Clamp
Jinyu Qiu, Minghui Li, Huiying Gong, Mingzhu Sun, Xin Zhao and Qili Zhao*
Institute of Robotics and Automatic Information System, Nankai University, China

- A novel robotic visual and electrical guided whole-cell patch clamp method was developed.
- The result on neurons in the V1 pyramidal cell layer in mouse brain slices shows that this method doubled the operation speed before cell sealing (3 min 35 s Vs 8 min), reduced the whole cell operation time by 44 and without reducing the success rate (60 Vs 60).

TuA2(3) 11:15–11:30
Simultaneous depth and viscoelasticity measurement of microstructures using echo effect in a photoacoustic imaging system
Wenxiu Zhao, Haibo Yu, Xiaoduo Wang, Lianqing Liu, and Wen Jung Li
Shenyang Institute of Automation, Chinese Academy of Sciences, China

- A photoacoustic method was utilized for viscoelasticity measurement when the depth is kept constant.
- Echo effect was utilized in a photoacoustic imaging system to measure viscoelasticity and depth simultaneously.
- Assisted by echo effect, there is no need to adjust the photoacoustic imaging system.

TuA2(4) 11:30–11:45
Design and Modeling of a Reloadable Coil-Delivery Instrument for Aneurysm
Chuanxiang Zhu, Yifan Wang, Yue Ding, Xiang Wang, and Kai Xu
School of Mechanical Engineering, Shanghai Jiao Tong University, China

- Design and manufacture a reloadable coil-delivery instrument to lower the cost of detachable coils.
- The coil is clamped by the claws made from nitinol rods and released by claw retraction.
- Model the large-deflection mechanics of pre-curved nitinol rods using elliptic integral.
- Experimentally verify the instrument’s function and the effectiveness of the mechanics model.

TuA2(5) 11:45–12:00
Positioning and Tracking of Neurons in Label-free Tissue Slice for Automatic Patch Clamping
Huiying Gong, Jinyu Qiu, Lu Li, Yatong Yao, Qili Zhao, Xin Zhao, Mingzhu Sun*
Institute of Robotics and Automatic Information System, Nankai University, China

- A positioning and tracking method of neurons in label-free tissue slice was proposed.
- Neuron selection, positioning, and segmentation were achieved by designing a two-step positioning algorithm based on convolutional neural networks.
- The contour obtained was used to track the target neuron consistently and accurately, since the neuron will shift as the pipette approaching.

The prototype of the reloadable coil-delivery instrument.
TuA3: Bio-inspired Robots
Session Chairs: Jianjun Yu and Wenyuan Chen
Room: Nan Shan B, 3/F, 10:45-12:00, Tuesday, December 28, 2021

**TuA3(1) 10:45-11:00**
Kinematics Analysis and Grasping Simulation of a Humanoid Underactuated Dexterous Hand

Xiangyan Zhang and Qinjian Zhang*
Beijing Information Science and Technology University, China
Haiyuan Li* and Bin Zhang
Beijing University of Posts and Telecommunications, China
Yingpeng Cai
Beijing Inspire Robots Technology Company, China

- The forward and inverse kinematics of the underactuated dexterous hand are derived.
- The workspace of a human hand and the dexterous hand are analyzed.
- The correctness of kinematic analysis is verified in simulation.
- Grasping different objects with appropriate actions is simulated.

**TuA3(2) 11:00-11:15**
Goal-driven Motion Control of Snake Robots with Onboard Cameras via Policy Improvement with Path Integrals

Lixing Liu, Xian Guo and Yongchun Fang
College of Artificial Intelligence, Nankai University, China.

- A periodic visual localization strategy is proposed to realize onboard visual localization.
- A two-stage motion control framework based on the PI2 and gait equation is proposed to realize the motion control of the goal-driven motion.

**TuA3(3) 11:15-11:30**
Bioinspiration to Robot Locomotion implementing 3D printed Foxtail Grass

Qing Lu, Behzadfar Mahtab, Fan Zhao, Ki-Young Song, and Yue Feng
School of Mechatronical Engineering, Beijing Institute of Technology, China

- 3D printing microfibers for anisotropic structure, mimicking foxtail grasses
- Bioinspired multipede robot
- Magnetic manipulation for locomotion control
- Simulation of stick-slip motion of the anisotropic structure

**TuA3(4) 11:30-11:45**
Bio-inspired continuum robot for out-pipe climbing and confined space navigating

Mingyuan Wang, Liang Du, Jianjun Yuan, Sheng Bao
Shanghai Robotics Institute, Shanghai University, Shanghai, China
Shugen Ma
Department of Robotics, Ritsumeikan University, Shiga, Japan.

- We propose a robotic solution based on continuum robot with compliant mechanisms
- This robot can imitate the locomotion principles of both caterpillars and inch-worms
- Dynamic simulations including task space motion and confined space navigating based on flexible multi-body dynamics method are performed, some phenomena are discussed.

**TuA3(5) 11:45–12:00**
Bio-inspired Soft (BIS) Hand for Tele-operated COVID-19 Ororharyngeal (OP) Swab Sampling

Jianshu Zhou, Wei Chen, Shing Shin Cheng, and Yunhui Liu
Mechanical and Automation Engineering, The Chinese University of Hong Kong, Hong Kong
Lingbin Xue, and Michael C F. Tong
The Department of Otolaryngology, Head and Neck Surgery, The Chinese University of Hong Kong, Hong Kong.

- In this work, we present a bio-inspired soft (BIS) hand dedicated to safe and dexterous OP swab sampling.
- The BIS hand is designed based on human hand sampling observation, which well replicates the pinch function of human fingers and orientation adjustment of the human wrist.
- A teleoperation-based controller with VF constrain is applied for intuitive teleoperation with safety guarantee.
- The results show our proposed BIS-hand enabled robotic system provides a human manual sampling comparable dexterity and safety.
TuA4: Teleoperation
Session Chairs: Hongpeng Wang and Bo Zhu
Room: Liang He Room, 3/F, 10:45-12:00, Tuesday, December 28, 2021

TuA4(1) 10:45-11:00
Robot-Enhanced Telepresence of Remote Teachers for Effective Distance Learning
Haozhe An, Michael Bowman, Songpo Li and Xiaoli Zhang
Colorado School of Mines, USA
- Distance learning is limited by the lack of physical interaction.
- Teleoperation empowers remote teachers to effectively communicate information.
- Learning experiences are improved with the teacher using the robotic system.

TuA4(2) 11:00-11:15
Robust Motion Mapping Between Human and Humanoids Using CycleAutoencoder
Matthew Stanley, Lingfeng Tao, and Xiaoli Zhang
Colorado School of Mines, USA
- Accurate and robust motion mapping between human and humanoid robots are required for intuitive robot control.
- Current models focus on accuracy (ability to map motion within the training workspace), but models should also be robust (apply mapping rules outside of the training workspace).
- Create CycleAutoencoder to improve robustness using three pairs of loss functions.

TuA4(3) 11:15-11:30
Evaluation of an Avatar Robot with a Physically Immersive Telepresence
Koen Hertenberg, Jose Salazar, Amir Tafreshi, Ankit Ravankar and Yasuhisa Hirata
Department of robotics, Tohoku University, Japan
- Elderly or disabled people might have difficulty going out and interact with their community.
- Common telecommunication and telepresence systems have limited interactivity and do not physically engage the users.
- We developed an immersive physically engaging telepresence system usable for elderly or disabled people.
- Researched the relationship between physical engagement and transported presence and immersion.

TuA4(4) 11:30-11:45
Teleoperation of the Tiangong-2 Space Manipulator System
Chongyang Li, Zainan Jiang, Yang Liu, Ziqi Liu and Hegao Cai
State Key Laboratory of Robotics and System, Harbin Institute of Technology, Harbin
- Two subsystem: the on-orbit teleoperation subsystem and the on-ground skill learning subsystem.
- Designing a on-ground mapping method of the CyberGlove based on the human and dexterous hand model.
- Establishing a grasping database and analyzing the variance between finger joints.
- Designing a on-orbit quick calibration method of the CyberGlove based variance analysis result.

TuA4(5) 11:45-12:00
Force Sensations of Delayed Telerobotic System with Kalman Filter
Hongbing Li and Xun Nie
Department of Instrument Science and Engineering, Shanghai Jiao Tong University, China
Evgent Magid and Dingkun Gui
- An estimation approach based on Kalman filter is proposed to deal with the dynamic interaction between robot with unknown environment.
- A Kalman filter based estimator has been designed to estimate the driving current and speed of the joint actuator.
- The feasibility of using motor current to estimate tool-environment contact forces is explored.
**TuA5: Actuators**

Session Chairs: Ying Zhang and Han Yuan

Room: Nan Hai Room, 3/F, 10:45-12:00, Tuesday, December 28, 2021

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**TuA5(1) 10:45–11:00**

**Experimental Analysis of the Vibrating modes of a Fish-Like Piezoelectric Actuated Beam**

Arthur Barbosa and Maria Martins
Mechanical Engineering Department, University of Sao Paulo, Brazil

- Impact Tests
- MFC Actuation
- Polynomial Approximation

Mode Shapes: (a) first (blue), (b) second (orange), and (c) third (green).

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**TuA5(2) 11:00–11:15**

**Design and Modeling of a Novel Biomimetic Variable Stiffness Actuator Inspired by Skeletal Muscle**

Yaowei Song, Yisheng Guan*, Chaoqun Xiang, Bin Wang, Zhihao Liang and Jie Wang
Biomimetic and Intelligent Robotics Lab (BIRL), Guangdong University of Technology, Guangzhou, China

- The biomimetic design of the variable stiffness actuator (BVSA) improves the compliance in human-robot interaction.
- The biomimetic representation of tendons and the muscle belly as cables and a composite compliant mechanism, respectively.
- The actuator weight and complexity are reduced, and the linearity of stiffness adjustment is improved.
- The stiffness characteristics of the BVSA are simulated, demonstrating a fine variable stiffness performance similar to that of skeletal muscle.

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**TuA5(3) 11:15–11:30**

**Dynamic Hysteresis modelling and Load Prediction for Pneumatic Artificial Muscles**

Ying Zhang, Yuhao Zhao, Meng Liu, Shuopeng Wang, Rixin Wang and Lina Hao
School of Mechanical Engineering & Automation, Northeastern University, Shenyang, 110819, China

- The load-dependent dynamic hysteresis of PAMs is tested and analyzed.
- A dynamic asymmetric hysteresis model of PAMs under different loading conditions is proposed.
- A new idea about load perception for the PAM is proposed.

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**TuA5(4) 11:30–11:45**

**Modeling, Analysis, and Experimental Results of the Skeleton-Embedded Fiber-Guided Water Hydraulic Actuator**

Siqing Chen¹, He Xu¹, Qiandiao Wei¹ and Weiwang Fan¹
¹Harbin Engineering University

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**TuA5(5) 11:45–12:00**

**Pneumatic Multi-Pocket Elastomer Actuator for Simulating Tendon Driven Human Muscles**

Jiang Wu and Motoki Shino
Department of Human and Engineered Environmental Studies, The University of Tokyo, Japan

- Focus on the actuator has the characteristics of softness and portability, which can safely and effectively couple the force of the actuator to the human body, often used in surgical support instruments and wearable devices.
- Devise a method to adjust the shape of the actuator during operation by changing the structure of the internal chamber and the external shape of the actuator.
TuB1: Surgical Robots I
Session Chairs: Yanding Qin and Yu Dang
Room: Phoenix Ballroom, 1/F, 13:00-14:15, Tuesday, December 28, 2021

TuB1(1) 13:00-13:15
Pre- and Intra-operative Dynamic Registration for Total Knee Arthroplasty Based on CT Image

Annotation
Yanding Qin, Mingqian Ma, Lin Shen, Zhihao Song, and Hongpeng Wang
College of Artificial Intelligence (Tianjin Key Laboratory of Intelligent Robotics), Nankai University, China
Institute of Intelligence Technology and Robotic Systems, Shenzhen Research Institute of Nankai University, China
Hongpeng Wang and Xinwei Chen
Fujian University Engineering Research Center, Minjiang University, China

- A robotic surgery system was proposed for total knee arthroplasty.
- The proposed surgical system includes navigation module and surgical operation module.
- A method based on CT image annotation was proposed to address the dynamic registration.

TuB1(2) 13:15-13:30
Penetration Identification Criterion and Augmentation for Pediatric Lumbar Puncture
Yiyun Wang and Hongbing Li
Department of Instrument Science and Engineering, Shanghai Jiao Tong University, China
Jing Zhang
Shanghai Children’s Medical Center, Shanghai Jiao Tong University School of Medicine, China

- This paper proposes a novel penetration criterion to sensitively capture the defining loss of resistance moment.
- Augmented haptic perception is realized to better inform the needle-tissue interaction while offering decent compliance with friction compensation.
- One-time success rate, insertion accuracy, operation confidence and stability is greatly improved with the compact mechanism and auxiliary system design.

TuB1(3) 13:30-13:45
Globally Learnable Point Set Registration Between 3D CT and Multi-view 2D X-ray Images of Hip Phantom
Jin Pan, Zhe Min, Ang Zhang, Han Ma
Rtr Lab, The Chinese University of Hong Kong
Max Q.-H. Meng
Rtr Lab, The Chinese University of Hong Kong

- We explore the Globally learnable 2D-3D Point Set Registration in multi-view settings.
- We implement the method in the real-world clinical dataset, hip joint dataset. The images captured from different views can speed up the convergence of searching and improve the accuracy.

TuB1(4) 13:45-14:00
An anthropomorphic surgical simulator arm based on series elastic actuators with haptic feedback
Sriranjan Rasakatla, Azumi Ueno, Antonio Galiza, Takahiro Ario, Ikuo Mizuuchi and Bipin Indurkhya
Tokyo University of Agriculture and Technology

Abstract—We present the Epsilon-1 surgical simulator, which was designed using series elastic actuators (SEA) with off-the-shelf components. This low-cost alternative provides surgical training to surgeons by providing haptic feedback from an environment simulated by physics engines. We describe the hardware and software architecture of the surgical trainer arm in this paper. This is the first Anthropomorphic surgical arm because its dimensions and motions are of anthropomorphic nature. We present here our intuitive software simulation environment that gives multiple views for the comfort of the surgeon trainee.

TuB1(5) 14:00-14:15
Towards Tracking by 2D-target Registration for Surgical Optical Tracking System
Tinghua Zhang, Zhengyan Zhang, Botao Lin, Junnan Xue, Jiaole Wang and Shuang Song
School of Mechanical Engineering and Automation, Harbin Institute of Technology (Shenzhen), China

- Question: The occlusion problem in OTS
- Solution: A tracking by 2D-target registration approach
- Contributions:
  - (1) Tracking the multi-marker 2D-target in a 3D point cloud registration manner;
  - (2) Occluded simulations and experiments were carried out.
A Practical SVD-based Ellipsoid Estimation for Active Modeling of Robotic Ureteroscope

Xiangyu Wang, Qingyi Zeng, Yanding Qin and Yongchun Fang
College of Artificial Intelligence, Nankai University, China

- The sequence processing technology is utilized to apply ESMIF to real-time active modeling of the robotic ureteroscope.
- The singular value decomposition is engaged on the envelope matrix of ellipsoid estimation to avoid possible numerical instability.
- The feasibility and robustness of the modified ellipsoid estimation are validated in active modeling of the robotic ureteroscope.

Mobile Sensor Array Tracking Approach for Electromagnetic Driven Capsule Robot

Yue Wan, Yujie Liu, Xiaoyang Wu, Shuang Song* and Jiaole Wang
School of Mechanical Engineering and Automation, Harbin Institute of Technology (Shenzhen), Shenzhen

- This paper proposed a mobile sensor array tracking approach for the capsule robot.
- The array is linked with the movable platform to ensure a widen-scale localization.
- The proposed method was to remove the partial magnetic field from the EM coil.

Cable Assembly in Constrained Environment Based on Contact State Transition Graph

Ruiqiang Wang, Dayuan Chen1, xin Jiang2, and yunhui Liu2
1Harbin Institute of Technology (Shenzhen), China
2The Chinese University of Hong Kong, China

- Use the vision system to track the cable shape in constrained environments.
- The manipulation sequence is planned taking consideration of the contact state transition graph which describes the contact state transition of the cable given specified action.
- The proposed method is verified by experiments in which a cable is inserted through a three-way pipe.

A Low-Cost Conductive-Textile Based Multifunctional Flexible Capacitive Sensor for Human Motion Tracking

Guopeng Zhou, Ran Zhao, Hanchen Yao and Houde Dai
Quanzhou Institute of Equipment Manufacturing, Chinese Academy of Sciences, China
Tim C. Lueft
Department of Mechanical Engineering, Technical University of Munich, Germany

- A flexible capacitive sensor based on conductive textiles is developed.
- The sensor is developed for multiple motion tracking tasks, i.e., stretching, pressing, and touching.
- It exhibits sensitivities of 0.21kPa-1, 0.06kPa-1 and 0.03kPa-1 for stretching, pressing and touching, respectively.

Relative State Estimation with Observer-based Intermittent Kalman Filter and Radial Basis Function Neural Network

Yujun Huang, Peihan Zhang and Wei Dong
Shanghai Jiao Tong University

- Multi sensor: Camera, IMU, UWB and T265
- Fusion scheme: IKF(Intermittent Kalman Filtering) and RBF(one Neural Network)
**TuB3: Mobile Robots I**

Session Chairs: Hesheng Wang and Yang Gao

Room: Nan Shan B, 3/F, 13:00-14:15, Tuesday, December 28, 2021

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**TuB3(1) 13:00–13:15**

**Human-Aware Robot Navigation Based on Asymmetric Gaussian Model**

Kunru Zhao, Lei Zhou, Zhengzi Hu, Shilei Cheng, Andong Shi, Yue Sun, Jingtai Liu

Institute of Robotics and Automatic Information System, Nankai University, China

- This paper proposes a navigation framework based on an asymmetric Gaussian model and pedestrian trajectory prediction.
- Using multiple Gaussian functions, the pedestrian speed and gaze direction are modeled, so as to obtain a more humanized comfortable space.
- Human comfort space and predicted trajectory are integrated into the navigation system, so that the robot can produce anthropomorphic trajectory.

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**TuB3(2) 13:15–13:30**

**Attacking End-to-End Visual Navigation Model: How Weak Existing Learning-Based Approaches Can Be?**

Hongye Wang, Kefan Jin and Hesheng Wang

Department of Automation, Shanghai Jiao Tong University, China

- A FGSM-based attacking method designed by minimizing the maximum value of the visual features.
- We solves the problems of branch activation uncertainties and the lack of labels.
- A general adversarial training framework which can overcome the proposed feature space attack.

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**TuB3(3) 13:30–13:45**

**Towards Minimally-Intrusive Navigation in Densely-Populated Pedestrian Flow**

Tong Zhou¹, Senmao Qi², Erli Lyu², Guangdu Cen², Jiaole Wang³, and Max Q.-H. Meng¹²

¹The Chinese University of Hong Kong, Hong Kong
²Harbin Institute of Technology (Shenzhen), China
³Southern University of Science and Technology, China

- Flow disturbance penalty and individual disturbance penalty are proposed to handle the macro and micro disturbance.
- Triangle-based sampling strategy is used to find the optimal and minimally intrusive trajectory.
- The results demonstrate that two penalty terms significantly improve the navigation performance in pedestrian flow.

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**TuB3(4) 13:45–14:00**

**Research on Driverless Vehicle Positioning Based on Simultaneous Localization and Mapping in Low Visibility Environment**

Wangxin Cao, Yang Gao, Hongrui Xia, Sen Kang

Chang’an University, Xi’an, China

- The work aims to improve the positioning accuracy and reduction of nonlinear optimization in a large-scale and low visibility environment.
- The HEAT image processing module is added to the front-end of the algorithm, which improves the contrast of the image while removing the darks.
- Introduction of CVAE processing information into SLAM to control the degree of non-degradability of the positioning algorithms.
- Results show that CVAE-SEAS algorithm has advantages in improving accuracy and robustness in the case of large-scale and low visibility environment.

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**TuB3(5) 14:00–14:15**

**Human-Aware Robot Navigation via Reinforcement Learning with Hindsight Experience Replay and Curriculum Learning**

Keyu Li¹, Ye Lu², and Max Q.-H. Meng¹²

¹Department of Electronic Engineering, The Chinese University of Hong Kong, Hong Kong, China
²Department of Electronic and Electrical Engineering, Southern University of Science and Technology, China

- In this work, an RL-based approach to efficient and collision-free navigation in a crowded environment is proposed.
- To address the sparse reward human-aware navigation problem, we incorporate the hindsight experience replay (HER) and curriculum learning (CL) techniques with RL to efficiently learn the optimal navigation policy.
- The results show that our method can effectively learn human-aware navigation without requiring additional demonstration data.
Grounding Language to Natural Human-Robot Interaction in Robot Navigation Tasks
Qingchuan Xu, Yang Hong, Yueyuan Zhang, Wenzheng Chi and Lining Sun
Robotics and Microsystems Center, School of Mechanical and Electric Engineering, Soochow University, Suzhou, China

- A new method to process natural language instructions given to the service is proposed.
- The proposed method does not need any corpus or labeled dataset.
- A NLIP based robot navigation framework is presented.
- Experimental studies demonstrate the effectiveness of the proposed method.

A demonstration path for the robot to navigate based on the natural language instruction.

A Human-Robot Collaboration System for Object Handover
Yifei Yang, Longzhong Lin, Yifan Zhang, Zhongxiang Zhou, Yue Wang and Rong Xiong
State Key Laboratory of Industrial Control Technology and Institute of Cyber-Systems and Control, Zhejiang University, China.

- Introduce a semi-automatic annotating method to facilitate dataset annotation
- Utilize REDE and Fast-SCNN to achieve fast and accurate pose estimation
- Make use of artificial potential field and admittance control to control robot arm perform a smooth follow-up movement
- Integrate computer vision and motion planning to form a Human-Robot Collaboration system, which can transfer object from robot to human successfully

The experiment platform

Mixed-Reality Human-Machine Interface

Mixed-Reality Human-Machine Interface

Learning Robotic Ultrasound Scanning Skills via Human Demonstrations and Guided Explorations
Xutian Deng, Yiting Chen and Miao Li
School of Power and Mechanical Engineering, Wuhan University, China
Fei Chen
Department of Mechanical and Automation Engineering, T-Stone Robotics Institute, The Chinese University of Hong Kong, Hong Kong

- We proposed a learning-based approach to learn the robotic ultrasound scanning skills from human demonstrations.
- The robotic ultrasound scanning skill is encapsulated into a high-dimensional multi-modal model.
- We leverage the power of imitation learning to train the multi-modal model with demonstrated data.
- A post-optimization procedure with guided explorations is proposed to improve the learned model.

The setup of our robotic ultrasound system.

Improving Human-Robot Interaction Safety through Compliant Motion Constraints in Bilateral Upper Limb Rehabilitation
Qing Miao, Bin Zhong, Chenyang Sun, Keqi Gao, and Mingming Zhang
Southern University of Science and Technology, China

- This paper contributes to robot-assisted bilateral upper limb rehabilitation via proposing a safety metrics.
- A safe interactive workspace is analyzed based on an end-effector robotic device.
- A compliant strategy that limits the movement inside of the workspace and prevents the handles impacting the boundary of the workspace.
Design of a Hopping Robot with Its Kinetics and Dynamics Analysis

Yuzhen Pan and Huiliang Shang*
Academy of Engineering and Technology, Fudan University, China

- A newly designed bionic hopping robot referring to hopping animals on an interactive simulation platform
- The hopping procedure with kinetics and dynamics analysis
- Use PID-controlled flywheel for attitude balance in case of rolling over
- Matlab-Adams collaborative simulation platform

Design of Six-Wheeled Planetary Rover with a Novel Hybrid Suspension

Sanfeng Hu and Jianguo Tao
State Key Laboratory of Robotics, Harbin Institute of Technology, China
Guoxing Wang
Beijing Spacecraft, Beijing, China

- A novel hybrid suspension of six-wheeled planetary rover based on serial articulated suspension is proposed.
- The geometric parameters of the hybrid suspension structure are optimized by using NSGA-II.
- Describes the movement strategy of the active mode of the hybrid suspension rover.
- The optimization results and motion strategy of active mode are verified by ADAMS simulation.

Design and Control of a Hydraulic Driven Robotic Gripper

Jiahui Qi, Xu Li, Zhenguo Tao, Haibo Feng and Yili Fu
State Key Laboratory of Robotics and System, Harbin Institute of Technology, China

- Design of a hydraulic driven three-finger gripper with linkage transmission.
- Kinematics and statics analysis for modeling and simulation.
- Position tracking and large load grasping experiments using PID controller.
- High load to-weight ratio.

Electric Vehicle Automatic Charging System Based on Vision-force Fusion

Dashun Guo, Liang Xie, Hongxiang Yu, Yue Wang and Rong Xiong
College of Control Science and Engineering, Zhejiang University, China

- System: Propose a complete method including perception, planning, and control for the electric vehicle automatic charging system.
- Sensor Fusion: Propose a hybrid vision-force modality for complex manipulation tasks.
- Sim2real: The whole system is trained in simulation and directly transferred to the real world without any fine-tuning

Design and Analysis of a Multi-Section Wire-driven Continuum Robot System with Variable Structures

Yujie Liu, Yue Wang, Shuang Song and Jiaole Wang
School of Mechanical Engineering and Automation, Harbin Institute of Technology (Shenzhen), China

- Design and analysis of a multi-section wire-driven continuum robot
- Kinematics model with both forward and inverse have been deducted.
- Workspace of the robot tip has been analyzed.

Session Chairs: Shan Guo and Hao Liu
Room: Nan Hai Room, 3/F, 13:00-14:15, Tuesday, December 28, 2021
Flexible Physiotherapy Massage Robot
Kefan Xing, Diangsheng Chen*, Ruilong Xue and Diwen Wang
Institute of Robotics, Beihang University, China

- The research in this paper designs a structure of flexible physiotherapy massage head.
- The silicone corrugated airbag can present different stiffness according to the input air pressure.
- This paper proposes human back visual recognition algorithm and massage path planning algorithm.

Object optimal grasping recognition method based on local point cloud model
HuiXiongZeng, NingHuang, YongXiang, Jun Li*
Laboratory of Robotics and Intelligent Systems, Quanzhou Institute of Equipment Manufacturing, Chinese Academy of Sciences, Quanzhou, China

- The closer the contour point set is to the center of the point cloud, the better.
- The smaller the average error between the fitting line and the points, the better.
- The more parallel the short side of the cuboid and the line fitted by the contour point set, the better.
- The more parallel the two lines fitted by two contour points set captured by a pair camera, the better.

LVIO-SAM: A Multi-sensor Fusion Odometry via Smoothing and Mapping
Ningning Dong*, Yanfan Li, Shaojie Zhou, Wenshan Zhan, Yuanqian Lu, and Liang Li
Intelligent Robot Research Center of Zhejiang Lab, Hangzhou, China

- A multi-sensor fusion odometry, LVIO-SAM, which fuses LiDAR, stereo camera, and inertial measurement, is verified using smoothing and mapping.
- We take advantage of the measurement results of LiDAR, stereo camera, and inertial sensors fine-tuning in a tightly coupled manner.
- We maintain a sliding window, which is updated using lidar and visual odometry, rather than observations like object pose features of Lidar scans and the tracked visual feature points to reconstruct the fusion system.
- For more details of experiments, you can visit our github: https://github.com/YanfanLi/LVIO-SAM and YouTube link: https://www.youtube.com/20210150

Flexible Physiotherapy Massage Robot Overall Technical Route

Modeling of robot grinding force variation based on curvature-position coupling
Xiaoyu Ren and Liqun Huang
Ubtech Robotics Corp., China
Mingguo Zhao
Department of Automation, Tsinghua University, China

- In order to explore the variation of grinding force during the grinding process, the mechanical model of grinding contact force needs to be developed.
- By combining with the functional relationship between curvature and maximum stress, the applied load should be decreased when the curvature of the workplace surface increases to make the grinding force keeps constant.

Prioritized Hierarchical Compliance Control for Dual-Arm Robot Stable Clamping
Xiaoyu Ren and Liqun Huang
Ubtech Robotics Corp., China
Mingguo Zhao
Department of Automation, Tsinghua University, China

- Propose a control framework to comply with two types of disturbances simultaneously and hierarchically.
- Optimize the internal wrench to ensure stable clamping under stochastic disturbances.
- Adopt the object admittance and joint space admittance to realize the compliance control.
- Solve the inverse kinematics of the dual-arm robot using hierarchical quadratic programming.

Automatic steel grabbing robot system for scrap steel processing production line
Rongsheng Wang and Bo Zhou
School of Automation, Southeast University, Nanjing
Yirong Liu
School of Automation, Southeast University, Nanjing

- grabbing robot prototype’s hardware architecture
- forward and reverse kinematics analysis
- trajectory planning of joint-space schemes and Cartesian-space schemes for actual
- MATLAB Simulations
The proposed algorithm is verified through serial machining based on the Lagrange multiplier method. The validity of the prediction was verified by comparing experimental, theoretical and simulation results.

Synchronous Motion Generation of Multiple Continuum Robots Based on a Jacobian-Estimation Strategy

Ning Tan, Ruikun Hu and Yuyang Wu
Sun Yat-sen University, China
Xinyu Zhang
East China Normal University, China
Fenglei Ni
State Key Laboratory of Robotics and System (HIT), China
Zhongyi Sun
The Chinese University of Hong Kong, Shenzhen, China

A novel model-free approach is proposed for the synchronous motion control problem of multiple continuum robots.

Synchronous motion control method

Dexterous Workspace Analysis of Industrial Robot for Machining Based on Service Sphere

Zhenya He1,2, Juming Wang1, Xiaomin Zhang1, Mingning Song1, Guolian Huang2, Jianzhong Fu1
2 Guangdong Provincial Key Laboratory of Precision Equipment and Manufacturing Technology, South China University of Technology, China
3 The State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University, China

A new expression method of the dexterity index based on service sphere was presented.

The dexterous workspace analysis for multi-axis machining

Joint Limit Optimal Inverse Kinematics of the 7-DoF Manipulator with Link Offset based on Semi-analytical Solution

Yaswen Zhang, Yeche Liu, Baoshi Cao, Yang Liu, Boyu Ma and Zongwu Xie
State Key Laboratory of Robotics and System, Harbin Institute of Technology, China

A semi-analytic inverse kinematic method proposed based on joint parameters

Configuration of the 7-DoF Manipulator on the Space Station
Towards Automatic Operation Motion Tracking Algorithm Based on Inertial Sensors for Multi Joints Machinery

Towards Automatic Operation Motion Tracking Algorithm Based on Inertial Sensors for Multi Joints Machinery

Maximizing the Use of Environmental Constraints: A Pushing-Based Hybrid Position/Force Assembly Skill for Contact-Rich Tasks

Enhanced Hybrid Position and Admittance Control Based on Nonholonomic Wheeled Mobile Manipulator with Redundancy

Research on Robot-assisted Accurate Location of Local Craniocebral Cooling Method

Deformation control method based on reaction current for soft pneumatic actuator actuated by electrochemical reactions

Room : Foyer, 1/F, 14:15-14:35, Tuesday, December 28, 2021
Design of a Patrol Robot Based on the Plug-In Service Architecture

Chen Jin, Xinggang Fan
Zhijiang College of Zhejiang University of Technology, China
Liyan Chen, and Shujia Qin*
Shenzhen Academy of Robotics, China

- Patrol robots have primarily worked in high-risk scenarios such as power equipment inspection and mining fields
- Surging demand from the market urgently asks for the flexibility of patrol robots’ architecture
- This paper introduces a plug-in-based design that adopts a three-layer architecture of hardware-end, back-end, and front-end to realize a patrol robot system with good maintainability and reusability
TuC1: Manipulation II
Session Chairs: Guohui Tian and Kunlong Hong
Room: Phoenix Ballroom, 1/F, 14:35-15:50, Tuesday, December 28, 2021

TuC1(1) 14:35–14:50
Manipulability-Oriented Configuration Transition Control of Continuum Surgical Manipulators Based on Velocity Polytopes
Yifan Wang, Yang Zheng, Longfei Wang, and Kai Xu
School of Mechanical Engineering, Shanghai Jiao Tong University, China
Bin Xu
Department of Urology, Shanghai Ninth People's Hospital, China

- The configuration transition inverse kinematics sometimes fails due to the reduced kinematic ability.
- Manipulability along the desired direction is characterized by the constrained velocity polytopes.
- Desired tasks are modified to guide the manipulator towards higher manipulability.
- Failure rate reduced from 5.56% to 0.32%.

TuC1(2) 14:50–15:05
Towards Components-of-Interest Feedback Control and State Estimation of Robotic Manipulator
Erli Lyu, Zhengyan Zhang, Jiaole Wang, Shuang Song
School of Mechanical Engineering and Automation, Harbin Institute of Technology (Shenzhen), China
Max Q.-H. Meng
Department of Electronic and Electrical Engineering of the Southern University of Science and Technology in Shenzhen, China

- Track the components-of-interest will accelerate the speed of tracking and improve the tracking precision.
- The end-effector could be moved to specified poses using nominal Jacobian matrix method with high precision while avoiding convex obstacles.
- Using inverse kinematic method could estimate the robot state based on the result end-effector pose.

TuC1(3) 15:05–15:20
A Joint Friction Model of Robotic Manipulator for Low-speed Motion
Yimin He, Sheng Bao, Jianjun Yuan and Liang Du
Shanghai Robotics Institute, Shanghai University, China
Shugen Ma
Department of Robotics, Ritsumeikan University, Japan
Weili Wan
Graduate School of Engineering Science, Osaka University, Japan

- Based on the Stribeck model, a joint friction model for low-speed motion were proposed.
- The model indicates that the joint friction and velocity are nonlinearly related, and the load torque affects the degree of nonlinearity.
- The proposed joint friction model can improve the accuracy of the robotic manipulator dynamics model.

TuC1(4) 15:20–15:35
Disturbance Observer based Fractional-order Control for Free-floating Space Manipulator
Xiangyu Shao, Hao Fu, Ouyang Zhang, Weiran Yao, and Guanghui Sun
Key Laboratory of Autonomous Intelligent Unmanned Systems, Harbin Institute of Technology, Harbin, China.

TuC1(5) 15:35–15:50
Review on Reinforcement Learning Controller in Soft Manipulator
Shuopeng Wang, Rixin Wang, Meng Liu, Ying Zhang and Lina Hao
School of Mechanical Engineering & Automation, Northeastern University, Shenyang 110819, China.

- Application of reinforcement learning on soft manipulators is summarized.
- The development prospects for the application of reinforcement learning controllers in soft manipulators are discussed.
- Some feasible methods in use are proposed based on the characteristics of the algorithm in different situations.
TuC2: Robot Design & Analysis II  
Session Chairs: Yu Dai and Yaowei Liu  
Room: Nan Shan A, 3/F, 14:35-15:50, Tuesday, December 28, 2021

TuC2(1) 14:35–14:50

A Multi-Fingered Robot Hand with Remote Center of Motion Mechanisms for Covering Joints with Soft Skin

Gagan Khullar, Alexander Schnitz, Chincheng Hsu, Prathamesh Sathe, Satoshi Funabashi, Shigeki Sugano  
Department of Modern Mechanical Eng., Waseda University, Tokyo, Japan

- Palmar side of the proposed hand is covered 97% with thick skin  
- 16 DOFs  
- The PIP and DIP coupling is integrated with remote center of motion mechanisms and makes fingers under-actuated  
- MCP joint of fingers (except the thumb) includes both flexion/extension and abduction/adduction DOF

TuC2(2) 14:50–15:05

Design Optimization of Y-Shaped Transmission System for Dual-Arm Concentric-Tube Robots

Chao Zhang, Guangdu Cen, Xing Yang, Jiaole Wang* and Shuang Song*  
School of Mechanical Engineering and Automation, Harbin Institute of Technology (Shenzhen), China  
Max Q.-H. Meng  
Department of Electronic Engineering, Southern University of Science and Technology, China

- This paper presents an optimal design framework of Y-shaped transmission system for dual-arm CTR.  
- Design constraints including geometric and deformation ones are deduced.  
- The design problem has been formulated as a constrained nonlinear optimization problem.  
- A dual-arm CTR prototype with the optimal Y-shaped transmission system has been built.

TuC2(3) 15:05–15:20

A Novel Modular Wheel-legged Mobile Robot with High Mobility

Qiang Fu, Yisheng Guan*, Shanwei Liu, and Haifei Zhu  
School of Electromechanical Engineering, Guangdong University of Technology, China

- Mobot-H can achieve locomotion in wheeled or legged modes, on continuous or discrete terrains  
- Mobot-H may be in different configurations for narrow environments such as small channels  
- Mobot-H adapts to inclined surfaces by adjusting the wheel orientation normal to the ground  
- Mobot-H can use a flipping-over gait to cross obstacles

TuC2(4) 15:20–15:35

Evaluating clearance parameters of 3D printed joints for the automated design of a non-assembly delta robot

Simon Schiele, The Nghia Nguyen and Tim C. Lüh  
Institute of Micro Technology and Medical Device Technology (MIMED)  
Department of Mechanical Engineering  
Technical University of Munich

- New non-assembly joint designs for powder-based additive manufacturing  
- Measuring appropriate clearance dimensions for different joint sizes and types  
- Realising a non-assembly delta robot

TuC2(5) 15:35–15:50

Simulation Platform for Autonomous Aerial Manipulation in Dynamic Environments

Fengyu Quan, Huisheng Huang, Hongjie Zeng, HanYao Chen  
School of Mechanical Engineering and Automation, HIT, China  
Yunhui Liu  
Department of Mechanical and Automation Engineering, CUHK, China

- Build up a modular simulation platform developed by combining software and hardware models  
- Proposed a novel aerial manipulating framework to realize an autonomous remote grasping in cluttered dynamic scenarios  
- The proposed approach only relies on onboard sensors, and considers dynamic obstacles existing on the pre-planned path
TuC3: Robot Learning
Session Chairs: Hongpeng Wang and Liang Zhao
Room: Nan Shan B, 3/F, 14:35-15:50, Tuesday, December 28, 2021

TuC3(1) 14:35-14:50

Training a Robotic Arm Movement with Deep Reinforcement Learning
Xiaohan Ni, Xin He and Takafumi Matsumaru
Graduate School of Information, Production and Systems, Waseda University, Japan

- Introduce a general experimental design scheme for training robotic arm by using DDPG
- Build an interactive reinforcement learning environment for robotic arm control task
- Set two different control tasks to verify the experimental design scheme

TuC3(3) 15:05-15:20

DFNN: Data Fusion Neural Network for Real-scene Reconstruction Model Inpainting of Nature Tree
Hongpeng Wang, Xiao Han, Zhongzhi Cao, Yaqing Li, and Xinwei Chen
AI school, Nan Kai University, China

- The experiments demonstrate the feasibility, efficiency, and effectiveness of our proposed method.
- Finally, the loss values of the trained generator and discriminator are 0.364 and 0.115 respectively, and the trained generator network inpainting the original model can satisfy the requirement for natural scene reconstruction.
- In this paper, we propose Data Fusion Neural Network (DFNN) to solve the problem of inpainting the natural tree reconstruction model, which is generating inpainting. The DFNN includes a generator network and a discriminator network.

TuC3(4) 15:20-15:35

Follow Me: Hierarchical Parallel Execution Synchronization in Behavior Trees
Yongjie Ma, Jiexin Zhang, Yunlong Wu and Yanzhen Wang
Artificial Intelligence Research Center, Defense Innovation Institute, China

- Introduce hierarchy into parallel tasks by dividing parallel tasks into leader and follower tasks.
- Propose two new parallel operators to solve the synchronous execution of parallel tasks in BTs.
- Integrate our approach into a popular BT framework and evaluate it by multiple experiments.
- Results show that our approach improves the parallel execution in traditional BT models.

TuC3(5) 15:35-15:50

YOEO - You Only Encode Once: A CNN for Embedded Object Detection and Semantic Segmentation
Florian Vahl and Jan Gutsche and Marc Bestmann
Informatics, Universität Hamburg, Germany

- Different outputs needed for Stuff (e.g. field, lines) and Things (e.g. ball, robot) classes
- Similar input features needed for both detection and segmentation
- Real time inference on embedded hardware
- Shared encoder to combine the feature extraction for both tasks

Application example in RoboCup Soccer
TuC4: System Design & Optimization I
Session Chairs: Yu Dang and Yang Gao
Room: Liang He Room, 3/F, 14:35-15:50, Tuesday, December 28, 2021

TuC4(1) 14:35–14:50
Efficient Inverse Kinematics Optimization Solution Method of Smooth Configuration for Hyper-redundant Robot
Yongqing Wang, Qingzi Yan, Te Li*, Guiben Tuo, Xu Li, Haibo Liu
Key Laboratory for Precision & Nontraditional Machining of Ministry of Education, Dalian University of Technology, Dalian, China

- An efficient inverse kinematics optimization solution method for hyper-redundant robot is proposed.
- The method is proposed to improve the solution efficiency and smoothness of inverse kinematics.
- The orientation accuracy of inverse kinematics is 60% higher than that of traditional PSO algorithms.
- The calculating time is reduced by 90% comparing with the result of pseudo inverse algorithm.

TuC4(2) 14:50–15:05
Design and Analysis of Scissor Extendable Airframe for a Morphing Multirotor
Tao Yang, Peng Li, Yuming Meng
Harbin Institute of Technology Shenzhen, China
Yanhu Liu
The Chinese University of Hong Kong, China

- Presents a general class of symmetric scissor extendable airframes (SEA) with one DOF for adjusting the size of multirotor in flight to various specific tasks and environments.
- Study the influence of design parameters on performance metrics for intuitively obtaining the performance of an SEA and helping design.
- Design and fabricate an SEA to show its morphing response time of 0.5 s., which enables multirotor to have rapid morphing capability.

TuC4(3) 15:05–15:20
Design and Experiment of a Soft Gripper Based on Cable-Driven Continuum Structures
Qiong Wu, Zhenglong Yi, Hongqiang Wang, Han Yuan*
School of Mechanical Engineering and Automation, Harbin Institute of Technology Shenzhen, China

- A novel cable-driven soft gripper, the shape and function of which are similar to a human hand was designed.
- Kinematic and kinetic models of the finger are established.
- Simulation analysis and finite element analysis are carried out to optimize the finger.
- Experimental validation proves that the gripper designed can realize stable self-adaptive grasping.

TuC4(4) 15:20–15:35
Automated Design of Snap-Fit Joints for the Additive Manufacturing of Robot Links
Samuel Detzel, Nico Besch, Benedikt L. Soballa, Renzo Bazan and Tim C. Lueth
Institute for Microtechnology and Medical Device Technology, Technical University of Munich, Germany

- Automated insertion of snap-fit joints into robot link geometries
- Automated feature recognition and geometric modification using a snap-fit feature library
- Minimized design and assembly effort
- Enabling fast and efficient redesign of additive manufactured robots

TuC4(5) 15:35–15:50
Direct Policy Optimization with Differentiable Physical Consistency for Dexterous Manipulation
Philipp Ruppel, Norman Hendrich and Jianwei Zhang
Department of Informatics, Universität Hamburg, Germany

- Policy network generates robot control signals and predicts contact points and forces.
- Weights are simultaneously optimized to fulfill task goals and to minimize a differentiable physical consistency loss.
- Dexterous manipulation tasks can be learned efficiently by single-level gradient-based optimization.
Study the adaptive optimal altitude control for UAVs.

- Study the adaptive optimal altitude control problem of the quadrotor UAV.
- The dynamics of altitude is modeled as a linear integrator model with nonlinear model uncertainties.
- Design a novel data-driven altitude controller based on the approximate dynamic programming.

Step response for the altitude control.

Dynamic Model of VTOL UAV

- Nonlinearities in the flight system.
- Parameters identification.

Simulation Results and Analysis

Quadrotor formation.

Geometric Formation Tracking of Aerial Robot Swarms Without Linear Velocity Measurements Over Directed Networks

- The main contribution of this work is to provide a solution for the formation tracking of the quadrotor UAV swarm without linear velocity measurements over the directed networks.
- The fiber-like auxiliary dynamic system is designed for each quadrotor to overcome the lack of the linear velocity measurements.
- The designed almost-global geometric attitude controller is the strongest possible controller in terms of the region of convergence.

TuC5: UAVs I

Session Chairs: Yanding Qin and Xiao Liang

Technical Sessions

Wednesday, December 29
Biped Robot Based on CPG and Muscle Attitude Module
This paper proposes a robotic fin actuated filter that allows for accurate predictions of superimposed fin module's trajectory. The proposed method can realize blind quadrupedal locomotion on terrains with robustness and energy efficient.

Cooperative Kinematics of Superimposed Fin Module
The proposed method can realize blind quadrupedal locomotion on terrains with robustness and energy efficient.

A learning-based control approach for blind quadrupedal locomotion with guided-DRL and hierarchical-DRL
A learning-based control method is proposed, where the parameters of control are learned by deep reinforcement learning (DRL). In the learning process, the guided-DRL and the hierarchical-DRL were used to solve the exploration problem and reward design problem, respectively.

Vision-based Navigation for a Small-scale Quadruped Robot Pegasus-Mini
- Implementation of a vision-based navigation using se-matic segmentation on a lightweight computing architecture deployed on a small-scale quadruped robot.
- Trajectory compensation method is proposed to enhance the success rate of the vision-based navigation for quadruped locomotion.

Bionic robotic fish attitude detection based on the limiting filtering-extended Kalman filter algorithm
Bionic robotic fish is one of the important researches for marine environment exploration in recent years. In the paper, a novel method of passive control for bionic robotic fish attitude detection is proposed based on the combination of a limiting filtering algorithm and an extended Kalman filter algorithm.
WePo3: Poster Session III (cont.)

Room: Foyer, 1/F, 10:40-11:00, Wednesday, December 29, 2021

**WePo3 2(7) 10:40-11:00**

Research on Disturbance of Upright Balance of Biped Humanoid Robot Based on ANMPSO-LQR
Jiayun Xu, Ruiyi Li, Dawenong Guo, Wei Liu, and Peng Liu

On the premise of ensuring the safety of the biped humanoid robot, this paper focuses on the issue of dynamic balance and disturbance in upright states. Considering the impact of model uncertainty on system performance, it is observed from the state that the current general control method is difficult to meet the requirements. In this study, a disturbance observer is designed to estimate and eliminate disturbances in the system. Based on this, a disturbance suppression control model is established. In the actual experiment, it is observed that the controller effectively rejects disturbances and maintains good balance performance.

**WePo3 2(8) 10:40-11:00**

A Learning from Demonstration Method for Generating Human-like Actions on Redundant Manipulators
Liang Zhao, Peng Yu, Tie Yang, Yang Yang and Lianqing Liu
State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, China
Ning Xi
Emerging Institute of Technologies and the Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Hong Kong

- A posture-mimicry-featured teleoperation interface for intuitive motion teaching and demonstration data collection
- A human-in-the-loop learning framework that can directly extract human-like features from demonstration.
- An efficient online relabeling approach that can relieve the workload of the human operator in the demonstration session.

**WePo3 2(9) 10:40-11:00**

Fast and Compliant Whole Body Control for Gear-Driven Torque Sensorless Quadruped Robot Trotting
B. Jin, C. Sun¹, D. Cheng, S. Ye, J. Su, A. Zhang
Shenzhen Institute of Artificial Intelligence and Robotics for Society (AIRS), The Chinese University of Hong Kong (CUHK), Shenzhen 518172, China

- A whole body control algorithm is proposed to generate the force model that can keep the robot balance during locomotion.
- A QP solver is utilized to distribute the force model to each joint.
- The hybrid force and position control is adopted in the low-level controller, to realize the variable stiffness control and improve the joint position tracking performance.
- A trajectory generator is used to plan the torso trajectory using SLIP.

**WePo3 2(10) 10:40-11:00**

Design of Quadruped robot single-leg system by Ionic polymer metal composites actuators array

**WePo3 2(11) 10:40-11:00**

Motion Acquisition of Vertical Jumping by a Bio-inspired Legged Robot via Deep Reinforcement Learning
Shinji Yamaguchi, Ryuki Sato and algou Ming
The Department of Mechanical Engineering and Intelligent Systems, The University of Electro-Communications, Japan

- The purpose is to make a bio-inspired legged robot learn a dynamic motion.
- DRL was used to learn vertical jumping and to acquire its general controller.
- The general controller was acquired by randomizing initial postures and environmental parameters during training.
- DRL enabled the robot to jump in various situations and to skillfully use dynamics.

**WePo3 2(12) 10:40-11:00**

Mechanical modeling of parallel muscles and guidance for actuation of manipulator
Jiayi Xu¹, Kangjie Fu², Yiyong Huang¹, Hongwei Liu¹ and Xiang Zhang²

¹ National Innovation Institute of Defense Technology, Academy of Military Sciences
² National Innovation Institute of Defense Technology
Learning a Push-Recovery Controller for Quadrupedal Robots
Peiyang Li, Wei Chen, Xinyu Han and Mingguo Zhao
Department of Automation, Tsinghua University, China

- We proposed a novel learning framework PHRL to resolve prioritized multi-objective problems.
- We utilized PHRL to learn a controller capable of push-recovery for quadrupedal robots.
- PHRL controller notably reduced robot's position error under external disturbance.
- PHRL learned faster than vanilla RL algorithms.

A Fuzzy ESO-based Joint Angle Control Design of Snake Robots
Lili Wu, Yang Liu, Junfang Zhou, Zhegang Wang, Xuhuang Wang, and Yingchen Tang
1) Beijing Electro-Mechanical Engineering Institute, 100074 Beijing, China
2) Key Lab of Intelligent Data Information Processing and Control of Hebei Province, Tangshan University, Tangshan, China
3) School of Electrical and Information Engineering, Tianjin University, Tianjin, China.

- The joint angle control of snake robots is designed based on FESO.
- The peaking phenomenon caused by initial estimation errors can be suppressed in the proposed FESO.
- The effectiveness of the designed joint angle controller is verified by simulations.

An Efficient Motor Synergy-based Control Strategy for Human Arm-like Robot
Hengyu Man, Dan Xiong, Yiyong Huang and Wei Han
1) National Innovation Institute of Defense Technology, Academy of Military Sciences
With the model predictive control (MPC), the control strategy for lane keeping is designed. A reference trajectory in the form of an exponential decay function is set. The key features in the demonstration include low computation, good obstacle avoidance, and real-time performance. The trajectory of our method in the ball interception task is shown.

The model-predictive-based trajectory generation method for RoboCup MSL competition is proposed. A motion-primitive-based trajectory generation method for robot operation is designed. A marker-less vision-based object tracking using HSV threshold technique is developed. The key features in the demonstration trajectory are extracted from angle information calculated among the adjacent waypoints.

A lane keeping control strategy that can achieve smooth steering operation is proposed. With the model predictive control (MPC), the control strategy for lane keeping is designed. A reference trajectory in the form of an exponential decay function is set for the performance variables.
WeA2: Underwater Robots

Session Chairs: Xiao Liang and Han Yuan

Room: Nan Shan A, 3/F, 11:00-12:30, Wednesday, December 29, 2021

WeA2(1) 11:00-11:15
Investigation on Yaw Stability of Bionic Propulsion in Flow Field
Guanwen Chen, Yuhan Li, Jiayong Chen, Ruxu Du, Yong Zhong
Shien-Ming Wu School of Intelligent Engineering, South China University of Technology, China

• The dynamic model of fish undulatory propulsion is constructed, considering the influence of flow field.
• The influence of rotation center position on the yaw stability of robotic fish is explored.
• The difference of yaw stability between bionic propulsion and screw-propeller propulsion is compared.

WeA2(2) 11:15-11:30
Direction Identification of Underwater Moving Target with Active Electrosense and CNN
Haoran Peng, Qiao Hu, Guangyu Jiang, Dan Xu and Tongqiang Fu
Department of Mechanical Engineering, Xi'an Jiaotong University, China

• Bio-inspired by weakly electric fish that discharge and sense electrical information
• Active electrosense array with vertically arranged transmitters and sensors
• CNN is used for the direction identification of underwater radial moving target
• Average identifying accuracy reached 84.72% and comparative experiments of sensor quantity were carried out

WeA2(3) 11:30-11:45
Mechanism Design, Kinematics and Hydrodynamics Simulation of a Novel Rocker Driving Bionic Robot
Zhongyin Zhang and Liwei Shi
The Ministry of Industry and Information Technology, Beijing Institute of Technology, China

• As shown in Fig.1, the characteristic mechanical structure of this paper mainly lies in three parts, i.e., Angle adjustment structure, crank and rocker mechanism and drive structure.
• The trajectory of crank is analyzed and the speed simulation is carried out.
• In this chapter, two analytical methods are proposed based on hydrodynamic simulation. These two methods complement each other and can provide reference for fin shape design.

WeA2(4) 11:45-12:00
Underwater Moving Object Localisation Based on Weak Electric Fish Sensing Principle and LSTM
Guangyu Jiang, Qiao Hu, Haoran Peng, Yu Liu, Sihu Li and Tongqiang Fu
School of Mechanical Engineering, Xi'an Jiaotong University, China

• Inspired by the biological sensing principle of weak electric fish
• Cylindrical underwater active electric field detection sensor array
• LSTM network with 6-layer architecture for moving object localisation
• The 2dmax is 5.38mm and 2dmin is 1.066% from pool experiment

WeA2(5) 12:00-12:15
Tracking Strategy of Robotic Fish Based on Multi-Sensor Distributed Detection Information Fusion
Youdong Chen, Jiawei Yang and Yong Zhong
Shien-Ming Wu School of Intelligent Engineering, South China University of Technology, China

• This paper adopts a low-cost infrared sensor with scarce sensing information as the primary sensor.
• We present the target tracking strategy based on multi-sensor distributed detection information fusion.
• Several sets of experiments are conducted to verify the effectiveness and robustness of the strategy.

WeA2(6) 12:15-12:30
Turning Maneuverability Analysis of a Bionic Gliding Robotic Dolphin
Yang Zhang, Zhengxing Wu, Jian Wang and Min Tan
The State Key Laboratory of Management and Control for Complex Systems, Institute of Automation, Chinese Academy of Sciences, China

• A novel gliding robotic dolphin with a special yaw joint is developed to pursue high turning maneuverability.
• Five turning patterns are selected to explore how the special mechanism as well as some key parameters affect the turning performance of the robotic dolphin.
• Various simulations are carried out to analyze the turning capability. The obtained results validate the effectiveness of these turning patterns for the bionic gliding robotic dolphin.
An Approach for sEMG-based Gesture Recognition using Continuous Wavelet Transform and AlexNet Convolutional Neural Network
Xu Zhu, Yongchao Lu, Tian Xu, Ramin Khushaba
School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, China

- A CWT-AlexNet model was proposed to realize gesture recognition.
- Based on Rami Khushaba EMG repository, the approach allows 99.95% classification accuracy for 10 gestures.

A Convolutional Neural Network With Multi-scale Kernel and Feature Fusion for sEMG-based Gesture Recognition
Lijun Han, Yongxiang Zou and Long Cheng
Institute of Automation, Chinese Academy of Sciences, China

- A Multi-scale Kernel and Feature Fusion Convolutional Neural Network (MKFF-CNN) is proposed.
- MKFF-CNN was evaluated on both the gForce dataset and the Ninapro DB6.
- MKFF-CNN achieves 97.65% accuracy on the gForce dataset, better than all the subnetworks.
- MKFF-CNN achieves 98.52% accuracy on the Ninapro DB6, 1.3% higher than the state-of-the-art works.

A Real-time sEMG-based Control Strategy and System for Contralaterally Controlled Functional Electrical Simulation
Xinyu Zhao, Ziyao Wang, Rui Xu, Dong Ming
Tianjin University, Tianjin, China

- Contralaterally controlled functional electrical stimulation has been proven to be effective in improving hand dexterity.
- The sEMG-based control strategy can be better used during grasping objects and bearing weights.
- This algorithm divides the function into three segments according to the sEMG under different conditions.
- Three out of six subjects’ correlation coefficients of the joint angles of the two wrists is greater than 0.95.

Improved Gait Posture Prediction in Transfemoral Amputees with Reconstructed Shank EMG Signals
Wenzi Zhang, Xinghao Wang1,2, Xiyuan Zhang3, and Zhenglong Song1,3
1School of Artificial Intelligence, University of Chinese Academy of Sciences, China
2AVIC Creative Robotics Co., Ltd, Xi'an, China
3Xi'an, China

- Address the problem for transfemoral amputees the lack of EMGs in the amputated part of the body poses a challenge in post-surgery prediction.
- Reconstruct Shank EMGs from thigh EMGs as input signal data.
- Confirm that the prediction system with reconstructed EMGs (reconstructed Shank EMGs = actual thigh EMGs recover 95.20% of the performance on average, comparing to prediction system using both thigh and shank EMGs.

A Mode-Specific Classification Based on sEMG for User-Independent Locomotion Transition Recognition
Ziyao Wang, Xingwei An, Rui Xu, Lin Ming and Dong Ming
Tianjin University, Tianjin, China

- The mode-specific classification strategy was used to distinguish seven locomotion modes, including four different transitions and improved the accuracy significantly.
- The user-independent recognition was discussed. The recognition accuracies of the proposed strategy was 95.14% with user-independent method.
- Further, the user-dependent and user-independent classification strategies from the thigh achieved accuracies of over 95% and 80%, respectively.

An sEMG-based Hill-type Model for Estimation of Swallowing Motion
Zhenhui Guo, Song Zhang, Yu Dang, Ningbo Yu and Jianda Han
College of Artificial Intelligence, Nankai University, China
Yue Wang, Jingqiao Wu, Yang Yu and Jialing Wu
Department of Rehabilitation Medicine, Tianjin Huanhu Hospital, China

- sEMG has been used for screening dysphagia but rarely for estimating swallowing motion.
- The sEMG signals and acceleration signals representing swallowing motion were collected simultaneously and preprocessed.
- The Hill-type model based on sEMG was established to estimation swallowing motion.
- The experiments tested 4 healthy subjects to verify the proposed method.
Collaborative Radio SLAM for Multiple Robots based on WiFi Fingerprint Similarity

Ran Liu, Zhenghong Qin, Hua Zhang, Billy Pik Lik Lau, Khairuldani Ismail, Achala Athukorala, Chau Yuen, Yong Liang Guan, and U-Xuan Tan
Southwest University of Science and Technology, China and Singapore
University of Technology and Design, Singapore

- We propose the collaborative radio SLAM to optimize the trajectory using a multiple-robot scenario based on fingerprint similarity.
- A new similarity measure that combines the received signal strength and the detection likelihood of the access point is proposed.
- Experiments are performed to validate the proposed similarity measure and our proposed collaborative SLAM solution.

Overview of our collaborative radio SLAM with two robots.

Robust Indoor Visual-Inertial SLAM with Pedestrian Detection

Heng Zhang, Ran Huang, Liang Yuan
College of Information Science & Technology, Beijing University of Chemical Technology, China

- A system built on ORB-SLAM3 with pedestrian detection
- Combining dynamic SLAM with the visual-inertial fusion, our system can achieve better robustness.
- A real-time dynamic SLAM algorithm with parallel tracking thread and segmentation thread.

Features detected by ORB-SLAM3 and our method.

Low-Drift RGB-D SLAM with Room Reconstruction Using Scene Understanding

Zefeng Ye and Yun-hui Liu
T Stone Robotics Institute, The Chinese University of Hong Kong, China
Xin Jiang
Department of Mechanical Engineering and Automation, Harbin Institute of Technology, China

- An efficient scene understanding method to detect wireframes and layout planes of buildings from RGB-D images.
- The global features (wireframes and layout planes) are integrated with point-based SLAM to improve the accuracy and robustness.
- A geometrically more meaningful map can be obtained from the proposed SLAM system.

The geometric SLAM map with wireframes and layout planes.

Construction Robot Localization System Based on Multi-sensor Fusion and 3D Construction Drawings

Xiang Li1, Xin Jiang*, Yunhui Liu2
1Harbin Institute of Technology (Shenzhen), China
2The Chinese University of Hong Kong, China

- We use multi-sensor fusion and 3D construction drawings to conduct global localization and position tracking.
- We propose an image-driven point cloud segmentation pipeline to filter the point cloud.
- We use unscented Kalman filter to fuse the point cloud registration pose with IMU.
- This system achieves higher accuracy than LiDAR SLAM localization.

Efficient Feature Extraction and Localizability Based Matching for Lidar SLAM

Lingfeng Dong1, Weidong Chen1, Jingchuan Wang1
1Medical Robotics and Department of Automation, Shanghai Jiao Tong University, China

- A lidar SLAM system for mobile robot running in feature sparse and degraded environments.
- A stable feature selection method based on PCA.
- Localizability is used to estimate the localization performance of robot and dynamically adjust the matching parameters.

Algorithm architecture.

Mapping While Following: 2D LiDAR SLAM in Indoor Dynamic Environments with a Person Tracker

Hongting Ye, Guangcheng Chen, Yisheng Guan
Biomimetic and Intelligent Robotics Lab (BIRL), Guangdong University of Technology
Weinan Chen, Li He, and Hong Zhang
Electronic and Information Engineering, Southern University of Science and Technology

- A framework combining people tracking and following with dynamic object removal in 2D LiDAR SLAM.
- Real-world experiments show that this framework is effective in handling dynamic obstacles and reducing the mapping error.

- A framework combining people tracking and following with dynamic object removal in 2D LiDAR SLAM.
A flexible pressure sensor was proposed to be integrated on a soft pneumatic gripper. The flexible pressure sensor can detect the interaction force of the soft pneumatic gripper. The soft pneumatic grippers were used to perform grasping capacity test.

The soft bending module with flexible sensing element.

A Soft Pneumatic Gripper Integrated with a Flexible Capacitive Pressure Sensor

Rui Liu, Jianxiong Hao, Xiaoyang Li, He Su, Chaoyang Shi
Key Laboratory of Mechanism Theory and Equipment Design of Ministry of Education, School of Mechanical Engineering, Tianjin University, Tianjin, China

A computational code of a bistable dielectric elastomer oscillator (DEO) was used and based on a soft robot, driven redundant soft manipulator. A bistable dielectric elastomer oscillator (DEO) inspired by the flying insects was developed. The bistable dielectric elastomer oscillator (DEO) has a high output performance than the monostable counterpart in lightly damped conditions. This design can have promising applications in bio-inspired robotics, energy harvesters, etc.

A novel insect-inspired ‘clicking’ dielectric elastomer oscillator for soft robotics

Lijin Chen and Weiwei Zhao
School of Mechanical and Electronic Engineering, Wuhan University of Technology, China
Research Centre for Medical Robotics and Minimally Invasive Surgical Devices, Shenzhen Institute of Advanced Technology (SIAT), China

Modeling, analysis and design of pneumatics networks soft actuators

Ying Liu¹ ², Xuan Wu¹, and Xiaojie Wang¹
¹Institute of Intelligent Machines, Hefei Institutes of Physical Science, Chinese Academy of Sciences, China
²University of Science and Technology of China, China

A Q-learning control method for a soft robotic arm

Utilizing Training Data from a Rough Simulator
Peijin Li¹, Gaotian Wang¹, Hao Jiang¹, Yusong Jin¹, Yinghao Gan¹, Xiaoping Chen², and Jianmin Ji²
¹The School of Computer Science, University of Science and Technology of China
²The School of Physical Science, University of Science and Technology of China

A Q-learning controller for a physical soft robot;
- With pre-trained models using data from a rough simulator;
- experiments with our physical soft robot, HPN Arm;
- Pre-trained models can reduce the amount of the real-world training data;
- Pre-trained models can also greatly improve accuracy and convergence rate.

The HPN Arm controlled in this work.

Shape and Force Sensing of a Soft SMA Planar Actuator for Soft Robots

Yiming Ouyang, Ru Jin, Hua Yang, Chuying Kong, Weihua Li, Xian Zhang

An SMA planar actuator (SPA) with a strain-gauge array sensing system;
A shape sensing method and a variable-stiffness beam model are proposed to realize the shape and one-dimensional external force sensing;
A shape reconstruction experiment and a force sensing experiment of a variable external force were implemented and the results validated the effectiveness and the accuracy of the above sensing methods.

Comparison of model, simulation and experiment.
WeB2: Mobilization & Learning
Session Chairs: Hesheng Wang and Liang Zhao
Room: Nan Shan A, 3/F, 13:30-15:00, Wednesday, December 29, 2021

A Survey on Deep-Learning Approaches for Vehicle Trajectory Prediction in Autonomous Driving
Jianbang Liu, Xinyu Mao, Yuqi Fang, Delong Zhu
CUHK, China
Max Q.-H. Meng
Electronic Eng., CUHK, China & Electrical and Electronic Eng., SUST, China

In this work, we survey some recent approaches for vehicle trajectory prediction and present some innovative ideas. The two main contributions are as follows:
1) Recent deep-learning approaches tackling trajectory prediction problems in driving scenarios are reviewed and discussed.
2) We implement the prediction model introduced by Zhao et al. and release our code to the research community.

NMF: an Efficient Method for Detecting the Fallen Leaves Using Cleaning Robots on the Road
Yanzi Miao and Zongwei Zhang
School of Information and Control Engineering, China University of Mining and Technology, China
Hesheng Wang
Department of Automation, Shanghai Jiao Tong University, China

‡ To deal with the dense leaves detection problem and improve navigation efficiency, we propose a Non-Maximum Fusion (NMF) algorithm.
‡ The experiments on the fallen leaves data set shows that NMF improves the fallen leaves detection coverage significantly.
‡ NMF greatly reduces the number of goal nodes for path planning.

Adaptive Locomotion Control of Sixteen-leg Robot based on Deep Reinforcement Learning
Xixi Mu, Shibo Shao, and Dong Zhang
College of Information Science and Technology, Beijing University of Chemical Technology, China

‡ The robot learns to move at speed of 14 17 m/s on a flat ground.
‡ The robot learns to locomote smoothly with a 350 kg load.
‡ The robot learns to traverse up on a slope of 40° from a plane.
‡ The robot learns to traverse down on a slope of 45° from a plane.

Pole-like Objects Mapping and Long-Term Robot Localization in Dynamic Urban Scenarios
Zhihao Wang, Silin Li, Ming Cao, Haoyao Chen
Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen, China
Yunhu Li
Mechanical and Automation Engineering, Chinese University of Hong Kong, China

‡ A method to extract semantic cluster from raw 3D LiDAR points and create semantic cluster map.
‡ A semantic cluster association algorithm based on geometric consistency is proposed to relocalize in long-term scenarios.
‡ A long-term and real-time localization system is developed based on the robust semantic cluster relocalization module.

Attitude Algorithm and Calculation of Limb Length Based on Motion Capture Data
Authors: Hesheng Wang, Jiaying Huang, Fan Yue and Xiaomin Zhang
WeB3: Dynamics & Control I
Session Chairs: Houde Dai and Yu Dai
Room: Nan Shan B, 3/F, 13:30-15:00, Wednesday, December 29, 2021

WeB3(1) 13:30–13:45
Highly Dynamic Bipedal Locomotion via an Improved Virtual Model Algorithm
Zhenqiu Zhu, Weiliang Zhu, Dongfeng Sun, Yimin Li, Jianmin Kong and Guotong Zhang

In this paper, we propose a new virtual model control (VMC) algorithm combining inverse dynamic control and estimation. We have shown how our approach significantly improves the dynamic performance of liquid robots with point feet and, thus, enables the point-based robot with excellent stability and high-speed movement ability.

WeB3(2) 13:45–14:00
Following Evaluation Index System for Service Robots in Dynamic Environments
Yue Sun, Meng Liu and Jingtai Liu*
Institute of Robotics and Automatic Information System and Tianjin Key Laboratory of Intelligent Robotics, Nankai University, China

• This paper proposes an evaluation index system of robot comfortable following.
• The method improves the psychological comfort of the followed human and other pedestrians.
• Service robots can show human-like social behaviors, which increases the degree of robots communicating with human and will be more acceptable to humans.

WeB3(3) 14:00–14:15
A Novel Hopping Height Controller with Positive Velocity Feedback for Hydraulic Actuated Legged Robot
Yan Yuan, Ce Li, Bo Gu, Mengtang Li, Beichen Ding*
School of Intelligent Systems Engineering, Sun Yat-sen University, China

• This paper proposes a novel hopping height controller with positive velocity feedback for hydraulic actuated robot.
• The proposed controller significantly reduces the number of measured variables without detecting the ground contact.
• Conditions for self-excited hopping are theoretically derived and it is successfully demonstrated via simulation using SYSU-HOPPER legged robot model.

WeB3(4) 14:15–14:30
The Icosahedron Marker for Robots 6-Dof Pose Estimation
Lunhui Duan, Hao Sun, Bokai Xuan, Yinglun Tan, Rui Cui and Mengkun Wu
School of Artificial Intelligence, Hebei University of Technology, China

• An improved monocular 6D pose estimation method based on the spatial icosahedron.
• Achieve translation accuracy of sub-millimeter level and rotation accuracy of less than 1°. Besides, it realized the 1180° large-scale rotation detection of three axes, and the real-time indicators is also satisfied.
• Higher Accuracy
• Higher detection stability
• Can cope with large changes in pose.

WeB3(5) 14:30–14:45
Putty Plastering Realized by a Force Controlled Robotic Scraper
Liu Zhao, Chen Dayuan and Jiang Xin
School of Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen, China

• We propose a putty plastering strategy based on a force controlled scraper which is mounted at the end-effector of an interior finishing robot.
• In order to control the quality of putty plastering, we verified several strategy including active parameters adjustment of impedance control, active adjustment of scraper speed/tilt angle.
• The plastering experiments in a construction site proved that the evenness and coated putty thickness can meet the quality requirements.

WeB3(6) 14:45–15:00
An Adaptive Force Control Architecture with Fast-Response and Robustness in Uncertain Environment
Xia Shuo, Fengxiang Ni, Kang Min, Tanchao Liu and Hong Cai
The State Key Laboratory of Robotics and System, Harbin Institute of Technology (HIT), Harbin, Heilongjiang, China

• It has the capability to compensate for environmental uncertainties.
• The experiment of tracking constant/variable desired forces in constant/variable stiffness environment and on an unknown shape surface are carried out.
• The results comparison condition that the proposed controller has superior in fast response and robustness in uncertain environments.

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**WeB4: Legged Robots**

**Session Chairs: Yong Jiang and Hao Liu**

Room: Liang He Room, 3/F, 13:30-15:00, Wednesday, December 29, 2021

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**WeB4(1) 13:30–13:45**

**Design of BRAVER - a bipedal robot actuated via proprioceptive electric motor**

Wenliang Zhu, Zhenguo Zhu, Xuewen Rong, Yibin Li and Guoteng Zhang

This paper provides a system overview about BRAVER, a lightweight bipedal robot designed for fast walking. BRAVER stands about 60cm tall, weighs approximately 4kg, and features 6 torque-controlled joints powered by proprioceptive electric motor with tendon drive on its legs. The paper describes design and implementation of control and presents details on hardware system such as incontrollability, hardware and sensors. Several experiments were carried out to prove that the bipedal robot could execute position and torque tracking robustly powered by proprioceptive electric motor.

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**WeB4(2) 13:45–14:00**

**Design and Analysis of the Leg Configuration for Biped Robots’ Spring-like Walking**

Ruilong Du, Sumian Song, Shiqiang Zhu, Daming Nie, Fangqian Shen, Haihui Yuan, Jason Gu and Mingguo Zhao

1. Intelligent Robot Research Center, Zhejiang Lab, China
2. Department of Automation, Tsinghua University, China
3. Department of Electrical Engineering, Dalhousie University, Canada

- This work presents a compliant leg configuration that satisfies SLIP model-based control.
- A numerical model was introduced to analyze the kinematics and the stiffness of the designed leg.
- Numerical analysis showed that the leg could be taken as a variable stiffness.
- Experiments were conducted on the leg prototype to verify the analysis of the stiffness.

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**WeB4(3) 14:00–14:15**

**Towards a more practical data-driven biped walking control**

Zhiyan Cao, Tianxu Bao, Wenchuan Jia*, Shugen Ma and Jianjun Yuan

School of Mechatronics Engineering and Automation, Shanghai University, Shanghai, China

- This control framework achieves a robust performance while closely keeping the style of the data.
- Decent bipedal action simulated by a balance strategy and a motion tracking controller.
- A cascaded position-velocity control with gravity compensation proposed for motion tracking control.

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**WeB4(4) 14:15–14:30**

**Agile Control For Quadruped Robot In Complex Environment Based on Deep Reinforcement Learning Method**

Hua Xiao, Shibo Shao and Dong Zhang

College of Information Science and Technology, Beijing University of Chemical Technology, China

- In this paper, a hierarchical training framework based on DDPG algorithm is proposed to solve complex tasks of quadruped robot.
- To assist the training of DDPG, different open-loop signals are introduced into the low-level network.
- The fact that high-level networks can receive different low-level strategies for completing tasks is also an advantage of our network’s structure.

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**WeB4(5) 14:30–14:45**

**Whole-body Motion Planning and Control for Underactuated Wheeled-bipedal Robots**

Yu Wang, Xianmin Xin, Xuewen Rong and Yibin Li

Shandong University

According to the dynamic analysis of the wheeled-bipedal robot model (WBRM), the horizontal posture of the robot is introduced into the reference to establish the kinematics with the torque as the state space. The whole-body forward (RBF) control is designed to establish the speed of each joint and the posture of the robot.
WeB5: BCI
Session Chairs: Yuliang Zhao and Bo Zhu
Room: Nan Hai Room, 3/F, 13:30-15:00, Wednesday, December 29, 2021

WeB5(1) 13:30–13:45
Joint Distribution Adaptation Network for Multi-source Electroencephalogram-based Emotion Recognition
Ying Tan, Gan Liu and Feng Duan
Department of Intelligence Science and Technology, Nankai University, China
Lingfeng Chen
School of Mathematics and Statistics, Xian Jiaotong University, China
Zhe Sun
Computational Engineering Applications Unit, RIKEN, Japan

- A JDAN model for multi-source EEG-based emotion recognition is proposed.
- The model includes joint distribution alignment and multi-classifier alignment.
- The model estimates the similarity between source and target domains by using joint distribution discrepancy.
- The model shows good performance in cross-subject experiment and cross-day experiment.

WeB5(2) 13:45–14:00
A brain-computer interface based semi-autonomous robotic system
Dengnan Xu, Yixin Tong, Xuyao Ding, Cong Wang, Liangqing Hua, Yiping Li, Qiwen Zhang and Xuefang Feng
Shenyang Institute of Automation, Chinese Academy of Sciences

- An fNIRS-based decoding of motor tasks is investigated for grip-force tasks.
- The results demonstrate the feasibility and potential of fNIRS-based decoding of motor tasks.

WeB5(3) 14:00–14:15
fNIRS Feature Extraction and Classification in Grip-Force Tasks
Jinrui Liu, Ting Song, Zhilin Shu, Jiaoda Han, Ningbo Yu*
College of Artificial Intelligence, Nankai University, China
Tianjin Key Laboratory of Intelligent Robotics, Nankai University, China
China Institute of Intelligent Technology and Robot Systems, Shenzhen Research Institute of Nankai University, China

- fNIRS measures brain activities in cortex and is of increasing research interest in study of brain function.
- fNIRS feature extraction and classification methods are investigated for grip-force tasks.
- The results demonstrate the feasibility and potential of fNIRS-based decoding of motor tasks.

WeB5(4) 14:15–14:30
A Novel Limb-Free Human-Computer Interface: Face-Computer Interface (FCI) with Channels Optimization
Bo Zhu, Daxi Zhang, Yiqi Chu and Xiangying Zhao
Shenyang Institute of Automation, CAS

- A FCI-based robotic arm for drinking water

WeB5(5) 14:30–14:45
Analysis of Psychological Structure in Mass Sense for Object Lifting Operation.
Kazunori Kodama, Kai Kondo, Yuta Namekata, Ryojun Ikeura, Shigeyoshi Tsutsumi, and Soichiro Hayakawa
Graduate school of Engineering, Mie University, Japan

- The subject of this study was the mass sense related to the lifting operation of a power-assisted device.
- We prepared an experimental setup that simulated the power-assisted device. The experiment consisted of a lifting operation with one vertical degree of freedom. The purpose of the study was to identify the psychological structure of the subject when the mass predicted by the subject differed from the mass actually lifted by the subject due to the generation of assist force. We adopted the semantic differential method for psychological evaluation.
- As a result of the experiment, we derived that the psychological structure of the sense of mass related to the lifting operation has an index of “stability” in the first place and an index of “comfort” in the second.

Abstract
The subject of this study was the mass sense related to the lifting operation of a power-assisted device.

- We prepared an experimental setup that simulated the power-assisted device. The experiment consisted of a lifting operation with one vertical degree of freedom. The purpose of the study was to identify the psychological structure of the subject when the mass predicted by the subject differed from the mass actually lifted by the subject due to the generation of assist force. We adopted the semantic differential method for psychological evaluation.
- As a result of the experiment, we derived that the psychological structure of the sense of mass related to the lifting operation has an index of “stability” in the first place and an index of “comfort” in the second.

Fig 3. Parameters used for description of motion equations

Fig 2. Operation of the subject

Fig 1. Separations used for description of motion equations

Fig 5. Example of a questionnaire (7 levels of answers)

Fig 5. Example of a questionnaire (7 levels of answers)
An Efficient Lightweight 2D Driven 3D Detector for Underwater Robots Tracking
Lu Chen, Zhengjia Zhu, Caiming Sun, and Aidong Zhang
Peng Cheng Laboratory (PCL), Shenzhen 518055, Guangdong, China
Shenzhen Institute of Artificial Intelligence and Robotics for Society (AIRS), the Chinese University of Hong Kong (CUHK), Shenzhen 518172, China

- A 2D driven 3D object detection and tracking framework was proposed.
- The proposed detection and tracking pipeline are lightweight and easily as well as rapidly deployed on an underwater robot.
- The pipeline achieved both high accuracy and high robustness in underwater robot leader-follower dynamic formation experiments.

Two underwater robots are tracking each other using 2D driven 3D detector and tracking pipeline.

Autonomous Legged Robot Navigation with Environment Awareness System in Complex Outdoor Environments
Jiamin Guo, Guanglin Lu, Teng Chen, Xuwen Rong, Yibin Li, Zhiying Wang, Haoning Zhao, Jialin Zhang
School of Control Science and Engineering, Shandong University, China

- The hybrid filtering algorithm can effectively reduce the data scale.
- The 5D space descriptor extracts more abundant topographic information.
- The VSSRRT could obtain a short path under the condition of fast convergence.

The Environment Awareness System of Autonomous Legged Robot

Flying Guide Dog: Walkable Path Discovery for the Visually Impaired Utilizing Drones and Transformer-based Semantic Segmentation
Haobin Tan, Chang Chen, Xinyu Luo, Jiaming Zhang, Constantin Seibold, Kaijun Yang, Rainer Stiefelhagen
CVHIC, Karlsruhe Institute of Technology, Germany

- Propose a “flying guide dog” prototype utilizing drone and semantic segmentation for visually impaired assistance.
- Develop a control algorithm to enable the drone to fly along the walkable path automatically.
- Introduce Pedestrian and Vehicle Traffic Lights (PVTL) dataset for traffic lights recognition.

A Generic View Planning Algorithm Based on Formal Description of Perception Tasks
Nanfeng Kong, Feng Zhu, Haibo Sun, Qun Wang and Zhiyuan Lin

- NLFNet, which is a semantic segmentation network that effectively integrates multimodal image data.
- Our network adaptively extracts complementary features of different modal input images.
- We conduct extensive experiments on different multimodal datasets and comprehensively analyze the effectiveness.

Qualitative result comparison between different networks.
Visual Place Recognition via Semantic and Geometric Descriptor for Automated Valet Parking

Jingrui Yu and Jianbo Su
Department of Automation, Shanghai Jiao Tong University, China

- Parking lot environments with sparse and repetitive textures, viewpoint variations and dynamic disturbances pose challenges for place recognition that is critical to AVP.
- The proposed descriptor consists of two parts: a semantic vector and a geometric histogram. A coarse-to-fine framework for place recognition is proposed based on that.
- The descriptor has the potential to establish data associations between different sensing modalities.

Self-supervised Attention Learning for Robot Control

Lin Cong, Yunlei Shi and Jianwei Zhang
University of Hamburg

- A coarse-to-fine framework for place recognition that is critical to AVP.
- The descriptor has the potential to establish data associations between different sensing modalities.

FRL-SLAM: A Fast, Robust and Lightweight SLAM System for Quadruped Robot Navigation

Chi Zhang, Zhong Yang, Qianhui Fang, Changliang Xu, and Hao Xu
College of Automation Engineering, Nanjing University of Aeronautics and Astronautics, China

- The bundle adjustment is restricted in a sliding window and the computation complexity is bound by marginalization scheme.
- The online rectifying of gravity vector enables roll and pitch to drift-free.
- The whole navigation system can run real time with CUDA accelerating on the embedded device carried by the quadruped robot.

Ground Enhanced RGB-D SLAM for Dynamic Environments

Rubin Guo1 and Xinghua Li2
1National University of Defense Technology, Hunan, China
2Academy of Military Science, Beijing, China

- Static and ground features are detected and tracked to provide reliable constraints.
- A point-ground based factor graph is constructed to derive the cost functions for localization and mapping.
- Keyframe dynamic regions are repaired by a hybrid method combining the point projection method and homography-based projection method.
Towards Real Time Interpretable Object Detection for UAV Platform by Saliency Maps
Maxwell Hogan and Nabil Aouf  
Department of Electrical and Electronic Engineering,  
City, University of London, United Kingdom

• Introduce an Image Tile Loader to improve small object detection from an aerial platform.  
• Demonstrate the enhanced performance of YOLOv5 and CenterNet-ResNet50 on small objects when using the Tile Loader.  
• Present the use of Grad-CAM to improve explainability of a network of YOLO style architecture.

A Classification Module for Automated Mosquito Surveillance Using Computer Vision
Masataka Fuchida and Ning Tan  
Sun Yat-sen University, China  
Hiroya Yatsuyanagi, Kazushige Okayasu and Akio Nakamura  
Tokyo Denki University, Japan  
Rajesh Elara Mohan  
Singapore University of Technology and Design, Singapore

• An automated computer-vision-based mosquito-detection module is proposed.  
• The design and implementation of two effective schemes for mosquito classification are reported.  
• The performance comparison of classification of mosquitoes and fruit fly using both schemes is conducted.

Topological Feature Based Object Matching for Traffic Light Detection Using Multi-view Camera System
Liyang Gao, Ming Yang, and Chunxiang Wang  
Department of Automation, Shanghai Jiao Tong University, China  
Yeqiang Qian  
University of Michigan-Shanghai Jiao Tong University Joint Institute, Shanghai Jiao Tong University, China

• Multi-view camera system for traffic light detection.  
• A new camera switching strategy with object matching and post-fusion algorithm.  
• Topological feature based object matching algorithm.

Real-Time Vision-Based Chinese Sign Language Recognition with Pose Estimation and Attention Network
Sirui Cheng and Chaorui Huang  
the School of Computer Science, Northeastern University, China  
Zhaoqiu Wang  
the Software College, Northeastern University, China

a. Introducing pose estimation in video sign language recognition, and improve the accuracy of the model.  
b. Our model based on multi-head attention and LSTM solves the problem under time series situations.  
c. Our methods have better results on mobile devices.  
d. Our methods, using pose key points, can eliminate the effects of volunteer gender, clothing etc.
To improve the treatment efficiency problem, the hemostatic pressure of the upper limbs is designed. A walking assistive robot system provides an automated and gentle winding of different diameters (82–104 mm) limbs. The hemostatic pressure of the upper limbs robot prototype is above 40 kPa.

First-aid Soft Constricting Hemostasis Robot Applied to Bleeding Limbs

Te Li, Kun Chen, Yuxin Li, Haibo Liu, Kai Ma, Yongqing Wang
Key Laboratory for Precision & Non-traditional Machining of Ministry of Education, Dalian University of Technology, China

- In earthquake and other disaster sites, the robot provides an unmanned automatic emergency stop bleeding.
- The soft hemostatic robot is inspired by humans to hold objects with fingers.
- A three-finger pneumatic arm realizes automatic and gentle winding of different diameters (82–104 mm) limbs.
- The hemostatic pressure of the upper limbs robot prototype is above 40 kPa.

A three-finger pneumatic arm realizes automatic and gentle winding of different diameters (82–104 mm) limbs.

Walking assistive robot system

An Integrated Software System Designed for Upper Limb Rehabilitation Robot

Yuhui Cen, Jianjun Yuan, Sheng Bao and Liang Du
Shanghai Robotics Institute, Shanghai University, China
Shugen Ma
Department of Robotics, Ritsumeikan University, Japan
Weiwei Wan
Graduate School of Engineering Science, Osaka University, Toyonaka, Japan

- To improve the treatment efficiency problem, an integrated software system is proposed.
- All information of therapists and patients is administrated digitally through a three-layer administration framework.
- A multi-modal training method library is developed to assist therapists in formulating individualized rehabilitation training programs.
- A safety protection strategy is proposed based on a joint angle filtering algorithm.

Architecture of the proposed software system

Haptic Bimanual System for Teleoperation of Time-Delayed Tasks

Aran Sena, Quentin Rouxel, Ekaterina Ivanova
1: Bioengineering, Imperial College London, UK
2: Informatics, University of Edinburgh, UK

- Future space missions aim to establish habitats on lunar and planetary surfaces, with robotic assembly systems performing the initial development of these facilities.
- We present a haptically controlled bimanual system, designed to investigate teleoperated assembly tasks, and better understand the associated challenges in time-delayed communications, mental load estimation, and variable autonomy.
WeC3: Robotic Exoskeletons
Session Chairs: Lianqing Liu and Wenyuan Chen
Room: Nan Shan B, 3/F, 15:30-16:45, Wednesday, December 29, 2021

WeC3(1) 15:30-15:45

A Biomimetic Tendon-driven Soft Hand Exoskeleton for Finger Extension based on Musculoskeletal and Biomechanical Principles
Wenyuan Chen, Ning Li, Wenxue Wang, Peng Yu, and Lianqing Liu
Department of Electrical and Computer Engineering, Swanson School of Engineering, University of Pittsburgh

- The human musculoskeletal model and sports biomechanical principles were analyzed for finger extension.
- A biomimetic tendon-driven soft hand exoskeleton was designed for finger extension.
- The stroke patient achieved a similar angular coupling relationship to the healthy subject.

WeC3(2) 15:45-16:00

Integration mode of standing balance and trajectory training based on lower limb rehabilitation exoskeleton
Tong Zhou, Jianjun Yuan, Sheng Bao and Liang Du
Shanghai Robotics Institute, Shanghai University, China

- An innovative rehabilitation exoskeleton prototype was proposed for balance training and gait training.
- Kinematics-based control model was applied to center of gravity transfer and trajectory planning.
- An integration mode of standing balance and trajectory training was designed to enhance rehabilitation training.

WeC3(3) 16:00-16:15

A Modular Lower Limb Exoskeleton System with RL Based Walking Assistance Control
Yutian Shen, Yingying Wang, Ziqi Zhao and Chenming Li
Electronic Engineering, The Chinese University of Hong Kong, HK, China

- A lower-limb exoskeleton system with compact design and modular actuation is presented to provide walking assistance.
- A reinforcement learning based control algorithm is proposed to provide assistance control where the exoskeleton-human system is modeled as a leader-follower system.
- Experiments are conducted on a built simulation platform with data partially collected from the exoskeleton-human system to validate the proposed controller.

WeC3(4) 16:15-16:30

Design and Modeling of a Novel Cable-Driven Elbow Joint Module for Humanoid Arms
Zhihao Liang, Yisheng Guan, Chaoqun Xiang and Yaowei Song
Guangdong University of Technology (GDUT) Guangzhou, Guangdong, China

- The modular design of the elbow improves the humanoid arm’s versatility and extensibility.
- The elbow module size and forms of motion are consistent with humans.
- The cable-driven method is used to ensure lightweight and flexibility.
- Elbow module forward and inverse kinematics of the anti-parallel mechanism are analyzed.

WeC3(5) 16:30-16:45

Stair and Ramp Recognition for Powered Lower Limb Exoskeletons
Konstantin Struebig, Niklas Ganter, Leon Freiberg and Tim C. Lueth
Chair of Micro Technology and Medical Device Technology, Technical University of Munich, Germany

- Machine vision for powered lower limb exoskeletons promises higher efficiency overcoming obstacles.
- The goal is to classify obstacles and measure their quantitative characteristics and distance.
- The proposed system uses a depth sensing stereo camera and the RANSAC algorithm.
- The system shows high accuracy, but suffers from long process run times.
WeC4: System Design & Optimization II
Session Chairs: Yong Jiang and Kunlong Hong
Room: Liang He Room, 3/F, 15:30-16:45, Wednesday, December 29, 2021

WeC4(1) 15:30–15:45

The Robot of Human Anti-visual Vertigo Ability Evaluation Based on Virtual Reality Technology
Jinbao Li, Tengfei Li, Haichuan Ren, Hang Li, Qiwei Shi, Xuan Liu, Xiong Chen
School of Electrical Engineering, Zhejiang University, China

- Visual vertigo is often caused by visual stimuli in life.
- The robot of human anti-visual vertigo ability is developed based on the virtual reality technology.
- Machine learning technology is used to quantitatively classify human anti-visual vertigo ability.

Fig. 1. The structure diagram of robot
1. Upper computer
2. Dynamometer
3. Single-channel EEG sensor
4. IR glass

WeC4(2) 15:45–16:00

Design of a Rigid-Flexible Coupling Origami Gripper
Dongbo Liang†, Yinghao Gao†, Hailin Huang, Bing Li
The School of Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen, China

- Rigid-flexible coupling gripper is developed by attaching stainless steel facets to the soft body of waterbomb mechanism, which increases its stiffness and therefore improved its load capacity.
- The rigid-flexible gripper is equipped with a sensory system composed of three self-made pressure sensors, which shows distinct responses to objects with different shapes.
- The sensory system shows ability to recognize grasping objects.

WeC4(3) 16:00–16:15

Design and Analysis of Multi-DOF Adsorption Parallel Robot Based on Hybrid Mechanism
Kefeng Ye‡, Zhenya He‡, Guojian Huang‡, Xianmin Zhang‡, Haolun Yuan, Liang Wang
1 School of Mechanical and Automotive Engineering, South China University of Technology, China
2 The State Key Laboratory of Fluid Power and Mechatronic Systems, Zhejiang University, China
3 School of Electrical Engineering, Guangdong Mechanical & Electrical, China

- The robot is composed of hybrid mechanism.
- The 3-RRR spherical parallel mechanism, and Delta parallel mechanism were designed respectively.
- The robot has 6 degrees of freedom, including 3 translational directions and 3 rotational directions.
- The adsorption mechanism based on the bionic design method was presented for in-situ machining.

Multi-DOF adsorption type parallel mechanism

WeC4(4) 16:15–16:30

A Cable-Driven Hyper-Redundant Robot with Angular Sensing
Yuxuan Mao‡, Jiangbo Yu‡, Long Wang‡, Yun Zou‡, Zecai Lin‡, Weidong Chen‡, and Anzhu Gao‡
1 Department of Mechanical Engineering, Shanghai Jiao Tong University, China
2 Science and Technology on Reliability and Environmental Engineering Laboratory, Beijing Institute of Structure and Environment Engineering, China
3 Department of Bioengineering, Shanghai Jiao Tong University, China

- Use algorithm of two-layer optimization to achieve the follow-the-leader control
- Use multi-sensor fusion (angle, force and position) to form a closed-loop control
- Feasible for different target curves in 3D.
- Average positioning error for the tip is 5.27 mm, regarding a length of 220 mm (3 sections)

The schematic diagram of the developed cable-driven multi-section robot.

WeC4(5) 16:30–16:45

CameraRoach: various electronic back packs for Search and Rescue
Sriranjan Rasakatla, Takeshi Suzuki, Wataru Tenma and Ikuo Mizuuchi
Tokyo University of Agriculture and Technology

Abstract—This paper describes a WiFi-enabled cyber-bionics equipped with a wireless camera to send video telemetry feedback to the controller for search and rescue. We developed new autonomous hardware and software for the neural stimulation of the cockroach to make it walk in a maze and send high-resolution video images to a computer. This system can be used for inspection or search and rescue. We describe our design of the cyber-bionics, and present results of an evaluation experiment. We describe our unique electronic backpacks we developed for the cyber-bionics which includes a GPS and a thermal camera.
WeC5: Dynamics & Control II
Session Chairs: Houde Dai and Yanding Qin
Room: Nan Hai Room, 3/F, 15:30-16:45, Wednesday, December 29, 2021

WeC5(1) 15:30–15:45

Design and Control of a Magnetic Driven Worm-like Micro-robot
Chupeng Tang and Hailin Huang
School of Mechanical Engineering and Technology, Harbin Institute of Technology, China

(1) Use a single soft sheet to realize the functions required by the robot;
(2) Driven by the external magnetic field to achieve untethered drive;
(3) Realize the real-time positioning of dual magnetic targets.

Magnetic driven worm-like micro-robot

WeC5(2) 15:45–16:00

Magnetic hydrogel for simultaneous flow control and drug release
Hongjie Jiang, Yi Ma and Longya Xiao
South China University of Technology

Showing a fluidic conductance of 0.76 µL/Pa*s/Gauss.

Showing a drug diffusion rate of 0.6% per min by 23 Gauss.

WeC5(3) 16:00–16:15

Design and Experimental Testing of a Compact High-Precision Magnetic Tracking System
Bowen Lv, Yanding Qin, and Jiahao Xu
Department Name, University Name, Country
College of Artificial Intelligence, Nankai University, China
Institute of Intelligence Technology and Robotic Systems, Shenzhen Research Institute of Nankai University, China
Houde Dai
Quanzhou Institute of Equipment Manufacturing, Haixi Institutes, Chinese Academy of Sciences, Jinjiang 362216, China.

- A high-precision magnetic localization system is established.
- The mean measurement error of 27 channels is 0.24 µT.
- During static tracking, the position and orientation error axially are less than 0.6 mm and 0.7°.
- The root mean square errors of position and orientation are 0.53 mm and 0.88°.

Schematic diagram of the magnetic localization scenario

WeC5(4) 16:15–16:30

Experimental Study on Dynamics of Open Loop Mechanism with Joint Clearance
Lixin Yang, Xianmin Zhang
School of Mechanical & Automotive Engineering, South China University of Technology, China

- An experimental system was designed to study the influence of multiple clearance joints on the displacement, velocity and acceleration of the open loop mechanism.
- The results show that the joint clearance has little influence on the end displacement and velocity of the test platform, but has a great influence on the acceleration, and produces high frequency vibration.

Experimental system of the open loop mechanism with clearance joints

WeC5(5) 16:30–16:45

Sequential and Distributed Auction Based Robots Task Allocation for Objects Assembly
Abdelhafid Zenati and Nabil Aouf
Department of Electrical and Electronic Engineering, City, University of London, United Kingdom

- The aim of this work is to equip the RWAs with the skills of cooperatively unloading heterogeneous objects.
- The global task allocation problem is translated to a mixed-integer nonlinear optimization problem (MINLO).
- We challenge the effectiveness of our approach on the above space exploration scenario.
- Our novel algorithm improves the distributed multi-robot task allocation results and achieves the desired aim of the work.
Technical Sessions

Thursday, December 30
Research on Lower Limb Movement Pattern Recognition Method Based on ReliefF-KPCA-SVM

Jinhua Zhang, Junding Guo, Hao Wang, Kexiang Li and Yan Zhao (Member)
School of Mechanical Engineering, Hebei University of Technology, Tianjin, China.

This paper innovatively proposes a lower limb motion pattern recognition method based on the combination of weighted feature selection algorithm (ReliefF), kernel principal component analysis (KPCA) and support vector machine (SVM), which can significantly reduce the complexity of data processing, effectively improve the accuracy of lower limb motion pattern recognition.

Continuous Motion Estimation of Lower Limb Joints Based on BP-KPCA Multi-Feature Fusion

Jinhua Zhang, Hao Wang, Junding Guo, Kexiang Li, Yan Zhao (Member)
School of Mechanical Engineering, Hebei University of Technology, Tianjin, China.

- Firstly, the time-domain characteristics of the presynaptic EMG signals of four muscles are extracted.
- Secondly, they are fused to remove the redundancy by KPCA and get several principal components with complementary information.
- Finally, four representative principal components are selected as inputs and imported into the prediction model. The experimental results show that the method can effectively predict the joint angle of lower limb movements.

Industrial Insert Robotic Assembly Based on Model-based Meta-Reinforcement Learning

Dong Liu, Xiaomin Zhang, Minghao Wang and Ming Cong
Dalian University of Technology, China
Yu Du
Dalian Jiaotong University, China
Dan Gao
Tangshan Polytechnic College, China

- Combine the compliance control and model-based meta-reinforcement learning method
- Realize the online adaptation by interacting with the environment and updating dynamic model in real-time
- Train a dynamics model in a simulation, and use the real assembly environment to test.

Grasping Objects Sequentially Using Expanded Segmentation Masks and Linear Combination of RGB-D Heightmaps

Guohui Tian, Hao Pan, Xuyang Shao, Zhongli Wang, Senyan Zhang and Cheng Song
The School of Control Science and Engineering, Shandong University, China

- This paper proposes a target-driven Sequential Grasping Network (SGN) to grasp objects sequentially.
- The neighborhood expansion of the mask based on the object size facilitates grasps.
- The linear combination of the RGB-D heightmaps reduces the size of the grasping policy network.
- The results show that the approach achieves a remarkable performance in the different scenes.
This paper proposes an improved network framework for the yolov4 algorithm, which improves the speed of detection and tracking. Firstly, the average sampling and down-sampling links of the PANet are strengthened with an increased CBAM attention mechanism, which improves the algorithm ability to deal with the objects occlusion. The depth separable convolution is introduced to reduce the amount of model parameters and improves the algorithm speed. Secondly, the SaNet attention mechanism is added to the residual module of CSPDarknet53 to pay more attention to the channel. Thirdly, Soft-NMS is used to optimize the screening of the detection frame during the detection process. Experiments show that the comparison of VOC2007 dataset is 84.26%, and in the VOC2007+VOC2012 dataset is 89.2%. The detection speed of FPS has increased by 2.21.

![An Improved Target Detection General Framework Based on yolov4](image)

**Abstract** — The speed and precision of the target detection algorithm have received wide attention in the application. This paper proposes an improved network framework for the yolov4 algorithm, which improves the speed of detection and tracking. Firstly, the average sampling and down-sampling links of the PANet are strengthened with an increased CBAM attention mechanism, which improves the algorithm ability to deal with the objects occlusion. The depth separable convolution is introduced to reduce the amount of model parameters and improves the algorithm speed. Secondly, the SaNet attention mechanism is added to the residual module of CSPDarknet53 to pay more attention to the channel. Thirdly, Soft-NMS is used to optimize the screening of the detection frame during the detection process. Experiments show that the comparison of VOC2007 dataset is 84.26%, and in the VOC2007+VOC2012 dataset is 89.2%. The detection speed of FPS has increased by 2.21.

**An Improved Target Detection General Framework Based on yolov4**

Liu Hao, Xin Shan and Zhang Lei
Beijing University of Civil Engineering and Architecture

**Displacement measurement of micro-nano flexible mechanism based on**

Yixi Zhang and Jianguang Li
School of Mechanical Engineering and Automation, Harbin Institute of Technology, China

**Deep Integrate Value Error for Trajectory Tracking Controller of Wheeled Inverted Pendulum Robot**

Yaqi Liu, Yidan Wang, Weipei Li, Tao Cao, Zhong Liu and Xian Gao
College of Artificial Intelligence, NanJing University, China

**A CNN-Based Position Control Method for Under-Actuated Cable-Driven Serpentine Manipulator**

Jiahao Tang1, Suo Zhang1, KangHao Wang1, Xuanming Gao1, Ning Tan1 and Zhengkang Tan2
School of Computer Science and Engineering, Tsinghua University, Beijing, China

1Tsinghua National Laboratory for Information Science and Technology (TNList), Tsinghua University, Beijing, China
2School of Computer Science and Engineering, Tsinghua University, Beijing, China
ThPo5: Poster Session V (cont.)

Room: Foyer, 1/F, 11:20-11:40, Thursday, December 30, 2021

ThPo5.3(13) 11:20–11:40

Machine Vision-based Identification and Positioning System for Domestic Garbage
Zhao Zhang*, Lei Zhang* and Shun Xin
Beijing University of Civil Engineering and Architecture

Domestic garbage classification is a global issue, and the robotic arm grasping system for garbage sorting can greatly improve sorting efficiency. Such robotic systems recognize and locate garbage by machine vision. The problems of existing garbage classification systems are as follows: the recognition rate of small-sized garbage is low; garbage positioning is inaccurate and time-consuming when the environment is dim or light-reflection. To this end, the paper collects 3168 images of domestic garbage, and divides them into 4 major categories and 22 minor categories, and then proposes an improved CenterNet target detection algorithm which is combined with the convolutional attention and feature fusing: normalized cross correlation matching algorithm has been referred to enhance the positioning accuracy in the light-reflection environment. In addition, pre-cutting and pre-matching are executed to improve object positioning. The experiments prove that the system can automatically complete the recognition and positioning of domestic garbage while ensuring accuracy and speed.

ThPo5.3(14) 11:20–11:40

3D Printed Optimization: Bayesian Neural Network Trade-Off between Cost and Load-Bearing
Xiaozhu Lin, Xianglong Tan, Longchuan Wang, Andre Rosendo
School of Information Science and Technology, ShanghaiTech University
Shanghai, China

*Our method is based on Bayesian Neural Network.
*The bridge is used as an example to validate the effectiveness.
*Our new method helps structural designers simplify the design process.
*Our results show that we can find the best design in 23 iterations.
*Experiment error between actual load-bearing capacity and the predicted value is below 4.682.

ThPo5.3(15) 11:20–11:40

Robotic Tactile Recognition system Based on AM-LSTM Model
Zhe Xu, Wei Yi, Muxin Chen
Department of Information, Beijing University of Technology, Beijing, China

• Established a tactile recognition system to create a tactile dataset OMT-13.
• In the process of verifying the AM-LSTM model in the dataset, it was found that the different closing speeds of the gripper has a certain impact on the accuracy of object recognition.

ThPo5.3(16) 11:20–11:40

A Deep Learning Network for Action Recognition Incorporating Temporal Attention Mechanism
Yue Liu, Xiaoxuan, Zhang Yu and Zhang Lei
Beijing University of Civil Engineering and Architecture

To address the problem that traditional action recognition methods do not perform well in complex video environments, in this paper a method for pedestrian action recognition in complex environments is proposed. A network for action recognition incorporating temporal attention mechanism is proposed. The main improvement of the method is as follows: Firstly, R-CNN network is used for pedestrian detection to get the locations of all pedestrians in video. Secondly, long and short term memory network (LSTM) is used to extract temporal features. On one hand, the network uses a residual part incorporating a spatial attention mechanism to extract the spatial features, which could reduce the interference from the image background. On the other hand, the Temporal Attention Mechanism (TAM) is proposed, which dynamically allocates video frames sequence weights according to the importance of LSTM output. Finally, experiments are conducted on the UCF101 dataset to verify the improvement of the accuracy and precision of the method.

ThPo5.3(17) 11:20–11:40

ICA and PIND based Remannder Particle Detection Technique for Space-borne Equipment
Zhishuai Jiang
Northeastern University at Qinhuangdao, China
Yuliang Zhao
Northeastern University at Qinhuangdao, China

• Particle impact noise detection (PIND) is usually used to detect remainder particle
• Independent component analysis (ICA) is an effective audio signal separation technology
• The system uses ICA technology to separate PINID sound and environmental noise
• Through many experiments, the accuracy of noise removal through ICA and PINID fusion method reaches 100%

ThPo5.3(18) 11:20–11:40

A non-rigid dynamic scene reconstruction method based on surface element model
Jiang Yong and Zeng Yujing
State Key Laboratory of Robotics, Shenyang Institute of Automation, China
College of Information Science and Engineering, Northeastern University, China
Du Jingbo and Wang Fei
College of Automation and Electrical Engineering, Shenyang Ligong University, China
Robotics Academy, Northeastern University, China

• I Foreword
• II General architecture for non-rigid scene reconstruction
• III 3D Scene Reconstruction Algorithm
• IV Experimental Analysis

3D reconstruction of model sequences from Boxing dataset.
**ThA1: Motion Planning I**
Session Chairs: Jiankun Wang and Zhao Guo
Room: Phoenix Ballroom, 1/F, 11:40-12:55, Thursday, December 30, 2021

**ThA1(1) 11:40-11:55**
CNN-based path planning on a map
Daniele Sartori\(^1\), Danping Zou\(^1\), Ling Pei\(^1\) and Wenxian Yu\(^1\)
\(^1\)Shanghai Jiao Tong University, Shanghai, China

**ThA1(2) 11:55-12:10**
WLAA*: A Time-efficient Method for Path Planning in Warehouse Environments
Maoqing Shi, Pengfei Duan, Tao Yu, and Shengwu Xiong
School of Computer and Artificial Intelligence, Wuhan University of Technology, China.
- A time-efficient method for path planning in warehouse environments.
- An algorithm that can identify the layout of a warehouse.
- 3 aspect simulation experiments prove the efficiency of the proposed method.

**ThA1(3) 12:10-12:25**
Graph-based Path Planning and ABC-optimized IT2FLS for Autonomous Mobile Robot Exploration Within Unknown Environments
Su Hong Yu, Xin Chen, Yujie Zhang, Wei Jie Li, and Hung Oguchi
\* An artificial bee colony (ABC) based internal type 2 fuzzy logic system (IT2FLS) for the trajectory tracking of mobile robots.

**ThA1(4) 12:25-12:40**
Learning-based Fast Path Planning in Complex Environments
Jianbang Liu, Baopu Li, Tingguang Li, Wenzheng Chi, Jiankun Wang\(^*\) and Max Q.-H. Meng\(^*\)
Our contributions are summarized as follows:
- A novel sampling method for fast path generation in complex environments;
- An efficient neural network to predict the promising region for the given complex environment;
- A series of case studies to demonstrate the advantage of the proposed algorithm.

**ThA1(5) 12:40-12:55**
A Nonuniform Sampling Strategy for Path Planning Using Heuristic-based Certificate Set
Han Ma, Jianbang Liu, Fei Meng, Jin Pan
Electronic Engineering, The Chinese University of Hong Kong, Hong Kong
Jiankun Wang and Max Q.-H. Meng
Electric and Electronic Engineering, Southern University of Science and Technology, China
- The heuristic-based certificate set consists of sampled states with collision status and the minimum distance to the nearest obstacle, while the heuristic is given by the neural network.
- The simulation results demonstrate that the nonuniform sampling strategy significantly speeds up the algorithms and improves their stability.
ThA2: Sensing & Estimation II
Session Chairs: Fei Wang and Hao Liu

ThA2(1) 11:40–11:55

Design and force analysis based on an integration of soft pneumatic ankle and toe actuating
Mingjing Guan, Lei Zhang*, Chengkun Li, Chunh Wang and Shuang Zhen

ThA2(2) 11:55–12:10

Magnetometer-Free IMU-Based Joint Axis Calibration and Estimation
Linhang Ju1, Lufan Mo1, Yanjun Shi1, Di Shi1 and Wuxiang Zhang1
1 Beihang University

ThA2(3) 12:10–12:25

Shape Predictions of a Flexible Rope Manipulated by a Robot Arm
Xiaolin Zheng, Conglian Li, Zhengyang Du and Ning Xi
University of Hong Kong

‡ A neural network is trained to predict a cable’s next state after being imposed a robot action
‡ A sampling-based action generating algorithm is designed and tested
‡ The prediction network and action generating algorithm are implemented in Gazebo Simulation

ThA2(4) 12:25–12:40

RF-Care: RFID-based Human Pose Estimation for Nursing-care Applications
Zihou Xia, Jixiao Liu and Shijie Guo
Hebei University of Technology

‡ RF Care-RFID Human Pose estimation for Nursing-care Applications
ThA3: Detection & Learning

Session Chairs: Guangyi Shi and Liang Zhao


ThA3(1) 11:40–11:55

Continuous eEMG estimation method of upper limb shoulder elbow torque based on CNN-LSTM

Cunjun Li, Jiankang Zhang, Haichi Li and Meixue Xu

School of Mechanical Engineering, Xi’an Jiaotong University, Shaanxi, China

- Committed to providing technical support for exoskeleton assist efficiency evaluation.
- According to the lifting process, a simplified two link model of the upper limb is established and the dynamic analysis is carried out.
- CNN-LSTM neural network is established to estimate the torque of upper limb shoulder and elbow joints.

ThA3(2) 11:55–12:10

An Algorithm on Checking 2-Finger Object Caging in Plane by Using Dual CC-Closure Region Concept

Koki Shirota, and Zhidong Wang

Department of Advanced Robotics, Chiba Institute of Technology, Japan

- In-plane two-finger caging problem is discussed in C-Object Closure Space.
- A Dual CC-Closure Region (DCCR) that can be used for checking of two-finger object caging with less calculation cost is proposed.
- Caging verification is reduced from SE(2) shape verification to a DCCR calculation in R² space plus a checking procedure of a circular arc path in R² space.

ThA3(3) 12:10–12:25

Active Semi-supervised Grasp Pose Detection with Geometric Consistency

Fan Bai and Delong Zhu and Hu Cheng and Peng Xu

Electronic Engineering, The Chinese University of Hong Kong, China

Max Q.-H. Meng

Electronic and Electrical Engineering, Southern University of Science and Technology, China

- This is the first work that leverages active learning and semi-supervised learning to solve the problem of grasp pose data.
- We propose the GCCoreSet strategy combining geometric consistency for core-set selection.
- We achieve semi-supervised training with labeled data and unlabeled data using geometric consistency constraints.
- The proposed method is tested on a general dataset and compared with other methods, achieving superior performance.

ThA3(4) 12:25–12:40

IEEE ROBIO 2021

Sanya, China, 27-31 DEC 2021

Title: Establishment and validation of the interference detection algorithm applied in limb deformity correction

Author: Guangyi Li, Jiankang Zhang, Mengjie Dong, Shuang Zuo, Ran Jiao, Shuang Wang

College of Mechanical Engineering and Applied Electronics Technology, Beijing University of Technology, Beijing, 100124, China

E-mail: dengjy@ustc.edu.cn

ThA3(5) 12:40–12:55

Distance Measurement Method Based on Neighborhood Mean Fitting Function

Fangdong Niu, Xiuling, Shifang Wu

School of Computer Science and Engineering, Southeast University, China

A novel distance measurement method based on the mean fitting function proposed.

- The relationship between the Gaussian function and the fitting function is analyzed theoretically.
- Using the advantages of the potential function's destructive property, the Gaussian model function is introduced to replace the traditional Gaussian function in the image domain, realizing the image precision of distance measurement.
**ThA4: Robot Vision I**

**Session Chairs:** Caiming Sun and Yaowei Liu

**Room:** Liang He Room, 3/F, 11:40-12:55, Thursday, December 30, 2021

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**ThA4(1) 11:40-11:55**

**View Loss Evaluation and Keyframe Reselection for Active Aerial Visual Reconstruction**

Yaojing Li and Hongpeng Wang and Xiaoyang Zhang and Jingtao Liu and Xinwei Chen

Nankai University, China, Shenzhen Research Institute of Nankai University, China Minjiang University, China

- Conduct quartered depth histogram feature to serve as observation for pose and position estimation.
- Define and classify the view loss to give a quantitative evaluation for keyframe reselection.
- Improve the quality of the 3D reconstruction by keyframe reselection method.

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**ThA4(2) 11:55-12:10**

**Robust Edge-Direct Visual Odometry based on CNN edge detection and Shi-Tomasi corner optimization**

Kengdong Lu1, Jintao Cheng1, Yubin Zhou1, Juncan Deng1, Rui Fan2, Kaiqing Luo1

1. School of Physics and Telecommunication Engineering, South China Normal University, Guangzhou 510006, P. R. China.
2. R. Fan is with the College of Electronic and Information Engineering, Tongji University, Shanghai 201804, P. R. China

- Combining CNN edge detection and Direct-VO into Edge-direct VO achieves excellent performance.
- Proposing an improved Shi-Tomasi corner optimization for edge maps.
- Combining the dual mechanism of periodicity and motion amplitude to update key frames.

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**ThA4(3) 12:10-12:25**

**Real-Time Flame Segmentation based on RGB-Thermal Fusion**

Shuaihao Guo, Biao Hu, Ran Huang

College of Information Science and Technology, Beijing University of Chemical Technology, China

- Designed a novel network model with an effective module, which can fuse RGB and thermal images for segmentation.
- The network model achieves superior performance than several state-of-the-art models on different datasets.
- RGB and thermal information is applied to the field of flame segmentation by deep learning.

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**ThA4(4) 12:25-12:40**

**Visual-Semantic Graph Attention Networks for Human-Object Interaction Detection**

Zhijun Liang1 and Junfa Liu1 and Yisheng Guan1 and Juan Rojas2

1. School of Mechatronic Engineering, Guangdong University of Technology, China.
2. Department of Mechanical and Automation Engineering, Chinese University of Hong Kong, China.

- Learning interactions between humans and objects is important for robot to further understand the visual world.
- Most previous works just leveraged local object-pair features while ignored informative cues from surrounding objects.
- A dual-graph attention network is proposed to consider contextual cues and intrinsic semantic regularities for HOI detection.
- Competitive results are obtained on two common benchmarks.

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**ThA4(5) 12:40-12:55**

**Small Defect Instance Reconstruction Based on 2D Connectivity-3D Probabilistic Voting**

Kunlong Hong, Hongguang Wang, and Bing Zhu

State Key Laboratory of Robotics, Shanghai Institute of Automation, Chinese Academy of Sciences, Shanghai, China

- Developed a novel method based on 2D connectivity-3D probabilistic voting for consistent reconstruction of small defects.

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*Some images in datasets.*

*Flowchart of the our method.*
ThA5: Planning & Control II
Session Chairs: Xiao Liang and Ningbo Yu

ThA5(1) 11:40-11:55

Single-Dimensional Intuitive teaching Control for Constrained Space Robotic Manipulation
Hang Gao¹, Zhang Xiaodong², Huanbin Xu², Tao Xiao² and Chao Ma¹
¹University of Science and Technology Beijing
²Beijing Institute of Spacecraft System Engineering

ThA5(2) 11:55-12:10

Visual Servoing Control of Concentric-tube Robot with Jacobian Matrix Estimation
Xing Yang¹, Guangdu Cen¹, Chao Zhang¹, Jiaole Wang¹, Shuang Song¹, Max Q.-H. Meng²
¹School of Mechanical Engineering and Automation, Harbin Institute of Technology (Shenzhen)
²Department of Electronic and Electrical Engineering, Southern University of Science and Technology

ThA5(3) 12:10-12:25

Continuous Finite-time Trajectory Tracking Control for Unmanned Quadrotor Transportation Systems
Yang Liu, Shizhen Wu, Zhaopeng Zhang, Xiao Liang, Jianda Han, Yongchun Fang
Institute of Robotics and Automatic Information System, Tianjin Key Laboratory of Intelligent Robotics, Nankai University, Tianjin 300350, China

ThA5(4) 12:25-12:40

Nonlinear Control for Dual-Rope Aerial Transportation System by Tilt-Rotor
Yang Wang, Hai Yu, Xiao Liang, Jianda Han, Yongchun Fang
Institute of Robotics and Automatic Information System, Tianjin Key Laboratory of Intelligent Robotics, Nankai University, Tianjin 300350, China

ThA5(5) 12:40-12:55

Dynamic Integral Sliding Mode for Vehicle Platoon Control with Constant Time Headway Policy
Yanbo Wang and Chenglin Liu
Key Laboratory of Advanced Process Control for Light Industry (Ministry of Education), Institute of Automation, Jiangnan University, China
ThB1: Motion Planning II
Session Chairs: Jiankun Wang and Shan Guo
Room: Phoenix Ballroom, 1/F, 14:00-15:30, Thursday, December 30, 2021

Efficient Planning for Object Search Task Based on Hierarchical POMDP
Wenrui Zhao and Weidong Chen
Institute of Medical Robotics and Department of Automation, Shanghai Jiao Tong University, and Key Laboratory of System Control and Information Processing, Ministry of Education, China

• Object search in clutter suffers from perception uncertainty and large action space
• Hierarchical POMDP is used to plan under uncertainty and reduce computation complexity
• Probabilities of action feasibility are learned in execution and are used to determine action feasibility in belief tree search
• Extra reward and advance identification are utilized to further reduce motion planning time

Hierarchical platoon motion planning strategy based on leader-follower structure
Lingli Yu, Zhengjiu Wang, and Zongxu Kuang
Department of Automation, Central South University, No.932 South Lushan Road, Changsha 410083, Hunan, China

• A hierarchical platoon motion planning strategy based on leader-follower structure is developed
• A quintic polynomial based method is proposed to generate initial trajectories
• Receding horizon optimization is presented to optimize the initial trajectories

A Trajectory Planning Method for Industrial Robot Weaving Welding Based on Piecewise Function
Chenhang Jiao, Hongwei Li
KUKA robot Guangdong Co., Ltd, China

• Employed the cycloidal trajectory in piecewise function
• Conducted the contrast experiments in MATLAB
• Conducted the welding experiment in real robot

Motion Planning for Hexapod Robots in Dynamic Rough Terrain Environments
Hangyi Xia, Kaiwei Che, Zhihong Tang, Junkun Wang, Member, IEEE, and Max Y.-H. Meng, Fellow, IEEE
Harbin Institute of Technology (Shen Zhen), China

We propose a novel integrated motion planner for hexapod robots in dynamic rough terrain environments. The planner consists of the RRT-based TEB algorithm and the TEB algorithm is used in the local planner. The simulation experiments results demonstrate that our proposed method can achieve better performance and the motion planning process for the hexapod robot.

Automatic Scan Planning and Construction Progress Monitoring in Unknown Building Scene
Hao Shen1, Xiang Li1, Xin Jiang1 and Yunhui Liu2
1Harbin Institute of Technology (Shen Zhen), China
2The Chinese University of Hong Kong, China

• The proposed method solves the scan planning problem in unknown building scenes, which combines the RRT and NBV algorithms utilizing the prior information involved in construction drawing.
• The completeness of wall construction will be estimated after the full coverage scan.
• The proposed method is verified by experiments in simulation, laboratory building and construction site.

Vision Based Polygon Detection System for Industrial Robots under Complex Illumination
Hao Gao1, Weidong Chen1, Ruimin Wu2
1Department of Automation, Shanghai Jiao Tong University, China
2Baoshan Iron & Steel Co. Ltd, China

• A polygon detection system for industrial robots under complex illumination.
• A image enhancement method based on histogram specification.
• A detection algorithm based on local features using a line segment detector.

Session Chairs: Jiankun Wang and Shan Guo
Room: Phoenix Ballroom, 1/F, 14:00-15:30, Thursday, December 30, 2021
In order to improve the UAV attitude fusion precision, a novel hybrid attitude fusion method is introduced in this paper. 

- An error model between the IMU output and attitude is established by a long short term memory neural network (LSTM NN).

- The attitude fusion error can be estimated well by using the powerful nonlinear fitting and time series processing ability of the LSTM.

A Novel Hybrid Attitude Fusion Method Based on LSTM Neural Network for Unmanned Aerial Vehicle

Liangli Li, Mingzeng Liu, Jichuan Liu, Chen Wei and Haibin Duan
The Department of Intelligence Science and Technology, Nankai University, P. R. China

The trained network can detect the target in the image at a very fast speed. The target tracking system controls the forward and backward movement and yaw angle change of UAV.

Fully Automated Control System for Recovery of Fixed-wing UAV

Hongyu Nie, Mengzi Zhang, Feng Gu, Lingling Chu, Guangyu Zhang, ;intian Du, and Xian Liu
Shenyang Institute of Automation, Chinese Academy of Sciences

1. An automated shipborne release and recovery system for fixed-wing UAV to achieve recycling deployment of fixed-wing UAV applied in the deep-sea.

2. An active flexible arresting hook is designed to compensate the rolling and pitch of the surface vehicle and dynamically match the attitude of the UAV.

3. Many ground and sea experiments and tests are conducted in different conditions to verify the feasibility and validity of the system.

ThB2: UAVs II
Session Chairs: Yu Dai and Yaowei Liu
Room: Nan Shan A, 3/F, 14:00-15:30, Thursday, December 30, 2021

ThB2(1) 14:00–14:15

Multi-UAV Interception Inspired by Harris’ Hawks Cooperative Hunting Behavior

Bingda Tong, Jichuan Liu, Chen Wei and Haibin Duan*, Senior Member, IEEE

This paper presents an approach to intercept adversarial unmanned aerial vehicle (UAV) by using Harris’ Hawks (Parabuteo unicinctus) cooperative hunting behavior. A mixed guidance law suited to the Harris’ hawks natural hunting style at high-speed is adopted for the leader UAV to intercept target UAV with good maneuverability and horizontal turning escape tactics. The “flush-and-sweep” strategy and “suck attack” strategy of Harris’ hawks used in cooperative hunting are introduced for multiple UAV’s interception in order to increase the probability of success.

ThB2(2) 14:15–14:30

The Development of a UAV Target Tracking System Based on YOLOv3-Tiny Object Detection Algorithm

Gan Liu, Ying Tan, Wenchuan Kuang, Binghua Li and Feng Duan
The Department of Intelligence Science and Technology, Nankai University, P. R. China

The Development of a UAV Target Tracking System

The Department of Intelligence Science and Technology, Nankai University, P. R. China

1. YOLOv3-Tiny target detection algorithm has a good effect in UAV target tracking system.

2. The trained network can detect the target in the image at a very fast speed.

3. Target tracking system controls the forward and backward movement and yaw angle change of UAV.
Balancing a pendulum on a horizontally moving cart is a classic benchmark problem for designing and testing control and reinforcement learning algorithms. Whereas vertically moving cart is seldom discussed due to relatively higher difficulty level in balancing the pendulum.

The trained agents learned oscillatory force inputs which successfully brought the pendulum to upright position and are able to balance the pendulum in vertical position oscillating within the displacement limits of the cart.

- A dual-loop dynamic adaptive impedance controller is proposed for force tracking of dual-arm manipulators.
- A dynamic adaptive impedance control is proposed to eliminate system oscillation and avoid force overshoot.
- Test results show that the proposed approach can achieve good force tracking performance in uncertain environment.

**Adaptive NN based Visual Servoing Control for Robot Manipulator with Field of View Constraint and Dynamic Uncertainties**

Jiao Jiang and Yaonan Wang
Electrical and Information Engineering, Hunan University, China

- Introduced a barrier Lyapunov function to design the controller of the visual servoing system.
- All signals of the closed-loop system are all restricted, while content the FOV constraints.
- The states of the closed-loop system finally converge to a compact set.
- Adaptive neural network control is applied to eliminate the uncertainties of the visual servoing system.

**Sensitive Collision Detection of Second-Order Generalized Momentum Flexible Cooperative Joints Based on Dynamic Feedforward Control**

Jie Wang, Yisheng Guan, Hailei Zhu, and Ning Xi
Biomimetic and Intelligent Robotics Lab (BIRL), Guangdong University of Technology, Guangzhou 510006, China

- Flexible joints for collaborative robots.
- External force detection based on second-order momentum observer.
- Sensitive collision detection and identification.

**A Dynamic Adaptive Impedance Controller for Force Tracking of Dual-arm Manipulators in Uncertain Contact Environment**

Xiaogang Song¹, Huan Mao¹, Hailin Huang¹, Wenfu Xu¹, and Bing Li²
1. School of Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen, 518055, China
2. Peng Cheng Laboratory, Shenzhen, 518055, China

- A dual-loop dynamic adaptive impedance controller is presented for force tracking of dual-arm manipulators.
- A dynamic adaptive impedance control is proposed to eliminate system oscillation and avoid force overshoot.
- Test results show that the proposed approach can achieve good force tracking performance in uncertain environment.

**Swinging Up and Balancing a Pendulum on a Vertically Moving Cart Using Reinforcement Learning**

Poorna Hima Vamsi A, Mangesh D Ratolikar, and R Prasanth Kumar

- Balancing a pendulum on a horizontally moving cart is a classic benchmark problem for designing and testing control and reinforcement learning algorithms.
- Whereas vertically moving cart is seldom discussed due to relatively higher difficulty level in balancing the pendulum.

The experiment platform
Fully Convolutional Networks for Automatically Generating Image Masks to Train Mask R-CNN

Hao Wu 1,2*, Jan Paul Siebert 2, Xiangrong Xu 1
1School of Mechanical Engineering, Anhui University of Technology, China
2School of Computing Science, University of Glasgow, UK.

- Proposes a novel automatically generating image masks method for the state-of-the-art Mask R-CNN deep learning method
- Implements a fully convolutional networks (FCN) based segmentation network to output object image masks for Mask R-CNN object detection
- Proposed method can obtain the image masks automatically with an over 90% mean of average precision (mAP) for segmentation.

Towards a Multispectral RGB-IR-UV-D Vision System — Seeing the Invisible in 3D

Tanhao Zhang, Lu Yin Hu and David Navarro-Alarcon
MECHANICAL ENGINEERING, The Hong Kong Polytechnic University, Hong Kong Special Administrative Region
Lu Li
MECHANICAL ENGINEERING, Chinese Academy of Sciences, China

- A Newly designed Multispectral Calibration Tool
- Methods of alignment of 3D Multispectral Images
- Evaluation of the calibration
- Test and experiment for automatic 3D image alignment

Algorithm for Crack Segmentation of Airport Runway Pavement under Complex Background based on Encoder and Decoder

Hai Feng Li, Pan Jing and Rui Huang
College of Computer Science and Technology, Civil Aviation University of China, China
Zhongcheng Gui
Shanghai Guimu Robot Co. Ltd., Shanghai, China

- Proposes the encoder-decoder segmentation algorithm, which provides foothold scheme is determined by potential field on point cloud data, and terrain passable terrain height map is constructed based on ground points in the height map.

Vision-based Terrain Perception of Quadruped Robots in Complex Environments

Kevin Wang, Teng Chen, Jian Bi, Yibin Li and Kueven Rong

Using a quadruped robot which equipped with a depth sensor to realize the perception of environmental terrain. Terrain height map is constructed based on point cloud data, and terrain passable scheme is determined by potential field algorithm, which provides foothold selection for robot motion planning. By integrating motion and depth vision, the robot can automatically perceive and adapt to the environment and terrain.
Can a Tesla Turbine be Utilised as a Non-Magnetic Actuator for MRI-Guided Robotic Interventions?

David Navarro-Alarcon, Luiza Labazanova, Man Kiu Chow and Kuen Wing Ng
The Hong Kong Polytechnic University
The Chinese University of Hong Kong

- A non-magnetic actuator to drive MRI-guided robots is presented.
- The motor design is based on a Tesla turbine.
- Its rotational motion is powered with pneumatics and measured with fibre optics.
- Experiments validate the proposed idea.

Pneumatically Actuated MR-Safe Parallel Robot for Deep Brain Stimulation Electrode Implantation

Wanhong Huang1, Zhonghao Dai1, Yanru Xu1, Qian He1, Zhaoping Huang2, and Anzhu Gao2
1. The School of Mechanical Engineering, Shanghai Jiao Tong University, China
2. The Institute of Medical Robotics, Shanghai Jiao Tong University, China

- A pneumatically actuated MR safe parallel robot for deep brain electrode implantation.
- A 6-DOF parallel robot is developed using six slider-crank mechanisms for prismatic motions.
- Inverse kinematics is built to investigate its workspace and achieve the precise control.
- The average error is 0.11 mm.

Preliminary Design of a Reconfigurable Cable-Driven Parallel Haptic Device Towards Robot-Assisted Surgery

Fansheng Meng, Changsheng Li1, Hao Wen, Rui Ma and Xingguang Duan
Department of Mechatronic Engineering, Beijing Institute of Technology, China
Weijun Zhang
Department of Beijing TINAVI Medical Technology Co., Ltd, China

- A novel reconfigurable cable-driven parallel haptic device with variable workspace and simple structures is proposed.
- The reduced inertia/weight of terminal and disturbance of the workspace are beneficial for operating.
- The rods can be fixed on the smooth surface freely to achieve the desired workspace.

Development of an Intra-Operative Active Navigation System for Robot-Assisted Surgery

Yiyang Meng, Yugen You, Pengxiu Geng, Zhichao Song, Yanding Qin
College of Artificial Intelligence (Tianjin Key Laboratory of Intelligent Robotics), Nankai University, China
Institute of Intelligent Technology and Robotic Systems, Shenzhen Research Institute of Nankai University, China

- An active navigation system was proposed to address the intra-operative vision occlusion.
- The proposed active navigation system includes multi-DOF robot, optical tracker and RGB-D camera.
- The static and dynamic positioning accuracy of OTS were investigated.
- An occlusion strategy was developed and experimentally tested.

Design and Simulation Experiments of a VR Based Tele-operated Surgical Robot System

Haiyuan Li1, Linlin Cui, Yuxuan Qiu, Lutao Yan
Beijing University of Posts and Telecommunications (BUPT), China
Qinjian Zhang
Beijing Information Science and Technology University, China

- A VR based master-slave heterogeneous minimally invasive surgical system as well as flexible robot instruments is presented.
- Master-slave intuitive and interactive control based on ROS and VR are designed.
- Simulation experiments with VR hardware are performed.

Enhanced Epidural Tissue Perception for Pediatric Patients by An Interactive Lumbar Puncture Simulator

Yuling Li and Hongbing Li
Department of Instrument Science and Engineering, Shanghai Jiao Tong University, China
Jing Zhang and Dingkun Gui

- This paper presents a novel training simulation system for spinal puncture surgery based on virtual reality technology and haptic feedback.
- The system allows the user to adjust the posture of the simulated probe by rotating the head and feel the spinal puncture force through a force feedback device.
ThPo6: Poster Session VI

Room: Foyer, 1/F, 15:30-15:50, Thursday, December 30, 2021

ThPo6(1) 15:30–15:50
Design of Tank Inspection Robot Navigation System Based on Virtual Reality
Hengyang Mu, Yifei Li, Diansheng Chen, Jiting Li and Min Wang
Institute of Robotics, Beihang University, China

• 3D modeling and rendering of the internal scene of the storage tank
• Full traversal path planning algorithm based on Matlab
• Match the pose of the virtual model and the real robot based on information and coordinate transformation
• Human-computer interaction interface design

ThPo6(2) 15:30–15:50
Human-machine security collaboration based on virtual collision sensor
Jianhua Zhang (Member), Hao Zhou, Yan Zhao (Member), Liwei Ci, Yang Lu, Yaoman Zhang, Xuan Liu
School of Mechanical Engineering, Hebei University of Technology, Tianjin, China

• A virtual collision sensor is proposed based on generalized momentum theorem for the master-slave task transformation algorithm. 
• This algorithm is suitable for obstacle avoidance in an unknown obstacle environment. It has the advantages of small computation and continuous change of avoidance speed.

ThPo6(3) 15:30–15:50
Exploring the Spatial Correlation of Shadowing in RF-based Device-Free Localization by Block Sparse Bayesian Learning
Jiaju Tan¹, Xin Zhao¹, Xuemei Guo² and Guoli Wang³
¹Nankai University, Nanjing, China
²Sun Yan-sen University

ThPo6(4) 15:30–15:50
Mechanical Design of a Supernumerary Robotic Finger for Grasping Abilities Compensation
Xuewei Lin, Xiaohui Xiao and Zhao Guo
School of Power and Mechanical Engineering, Wuhan University, China

• A supernumerary robotic finger (SRF), which is portable and wearable
• Compensate grasping abilities by a bionic mechanical finger
• Control the mechanical finger by obtaining the posture of the user’s little finger
• Use mechanical structure instead of sEMG signal to obtain posture

ThPo6(5) 15:30–15:50
A Reconfigurable and Deployable Mechanism for In-pipe Manipulation Robot
Jingyu He, Shuangguo Li¹, Hongkui Zhao, Zhiying Shen and Man Diao
Beihang University

• A reconfigurable and deployable mechanism for in-pipe manipulation robot

ThPo6(6) 15:30–15:50
A Novel Unmanned Surface Vehicle with 2D-3D Fused Perception and Obstacle Avoidance Module
Zhe Chen¹, Baoxing Jiang², Zhejing Ruo², Zhongfa Zuo², Jinhong Xu¹ and Hong Li¹
¹Institute of Robotics, Beihang University, China

Unmanned surface vehicles (USVs) are important intelligent equipment that can accomplish various tasks on open area marine. During operation, environmental perception and obstacle avoidance is of vital significance to its autonomy. In this paper, we propose a novel USV equipped with fused perception and obstacle avoidance module that contains robust perception, localization and effective obstacle avoidance strategy. The new module is named Three-Dimensional Perception Module (PMTD), which utilizes camera and LiDAR to integrate multi-dimensional environmental information. It is able to detect, identify and track target objects in the process of autonomous travel. The localization precision achieves a centimeter-level with GPS and IMU devices. Meanwhile, the obstacle avoidance strategy allows the USV to efficiently keep away from static and dynamic floating objects in water areas. Through real-world experiments, we show that with the help of the proposed module, the USV can complete stable and autonomous operation and obstacles avoidance path planning even without any manual intervention. This indicates the strong ability of the module in autonomous driving for USVs.
**Quadrotor Trajectory Planning for Visibility-aware Target Following**

Lele Xi, Xinyi Wang, Yulong Ding, Yue Wei, Zhihong Peng, and Ben M. Chen

1. School of Automation, Beijing Institute of Technology, China
2. Department of Mechanical and Automation Engineering, The Chinese University of Hong Kong, China
3. Peng Cheng Laboratory, China

- Target following
- Visibility-aware
- Smooth quadrotor trajectory planning
- Cluttered environment

See the experimental video

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**Research on Safe Motion Tracking Algorithm of Manipulator Based on Minimum Pseudo-Distance Criterion**

Xufei Liu, Hei Zhang, Xiongping Su*, Fei Zhou, Hongyi Hu, and Junwei Zhang

1. School of Electrical Engineering, University of Electronic Science and Technology of China
2. College of Intelligent Science and Technology, National University of Defense Technology, China
3. Science and Technology on Robot Application Laboratory, Ministry of Industry and Information Technology, China

- Design a distributed area persistent coverage algorithm for the multi-UAV system.
- Consider the detection probability of the sensor and the importance of different areas.
- Use the distributed anti-rocking method to among UAVs.
- Simulations show that the algorithm can achieve continuous and stable coverage of the task area.

---

**A New Scheme for Cooperative Hunting Tasks with Multiple Targets in Dynamic Environments**

Ruikun Hu and Ning Tan

School of Computer Science and Engineering, Sun Yat-sen University, China
Fenglei Ni
State Key Laboratory of Robotics and Systems (HIT), China

- A new scheme for cooperative hunting tasks with multiple targets in dynamic environments is proposed.
- The multi-target k-WTA algorithm achieves the task allocation for hunting multiple targets with high efficiency.
- The wolf-pack-particle-based model guides robots to cooperatively hunt targets and achieves dynamic obstacle avoidance.

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**A Distributed Persistent Coverage Algorithm of Multiple Unmanned Aerial Vehicles in Complex Mission Areas**

Mengge Zhang, Huiming Li, Jie Li, and Xiangke Wang

College of Intelligence Science and Technology, National University of Defense Technology, China

- Design a distributed area persistent coverage algorithm for the multi-UAV system.
- Consider the detection probability of the sensor and the importance of different areas.
- Use the distributed anti-rocking method to among UAVs.
- Simulations show that the algorithm can achieve continuous and stable coverage of the task area.
ThPo6: Poster Session VI (cont.)

Room: Foyer, 1/F, 15:30-15:50, Thursday, December 30, 2021

ThPo6.3(13) 15:30–15:50
Autonomous Landing of a Rotor Unmanned Aerial Vehicle on a Boat Using Image-Based Visual Servoing
Lingjiao Yang, Zhikang Jin, Xiangke Wang, Guanzhong Wang, Xiaoyu He, Yuxin Xi
College of Intelligence Science and Technology, National University of Defense Technology, China

- Propose an IRIS method for a rotor UAV to land on a boat with a downward-looking camera.
- The virtual camera method is adopted to compensate the effect of UAV’s attitude change.
- A novel 2D landing tag is designed to ensure detection within a large altitude range.
- Introduce Kalman filter to optimally estimate the position of the feature points with observation noise.
- Both simulation experiments based on Gazebo and field experiments based on the deck simulation platform are conducted.

ThPo6.3(14) 15:30–15:50
Trajectory Tracking Control of Uncertain Euler-Lagrange Systems: A Robust Control Approach
Xingxiu He, Maobin Lu and Fang Deng
School of Automation, Beijing Institute of Technology, China

- A robust controller instead of adaptive controller is proposed.
- A strict Lyapunov function is constructed.
- Use the relative position and relative velocity information in the controller.

ThPo6.3(15) 15:30–15:50
Collision-free Trajectory Generation for UAV Swarm Formation Rendezvous
Weiming Qing and Yongxin Yin
CH UAV Department, China Academy of Aerospace Aerodynamics, China
Hao Chen and Xiangke Wang
College of Intelligence Science and Technology, National University of Defense Technology, China

- Solve a UAV swarm rendezvous problem with spatial-temporal and safe-critical constraints using two-stage strategies.
- Offline planning provides a near-optimal solution for real-time online decision-making, which is based on ACO with elite strategy and minimum-snap algorithm with safe corridors.
- Online planning incorporates the zeroing control barrier function constraints and the offline trajectories for absolute collision avoidance.

ThPo6.3(16) 15:30–15:50
Path Planning Based on Segmented Bezier Curves and A* Algorithm for Mobile Robot
Yong Zhang
National Astronomical Observatories / Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, China

- An optimized path planning method based on segmented Bezier curves and A* algorithm for mobile robots is presented. A* algorithm is used to guide the generation of Bezier curves. While the segmented Bezier curve is designed to ensure that the robot can avoid obstacle.
- The determination of segment points, control points and the optimization of path selection are crucial parts of the method. The optimized Bezier curve for each segmented A* path is selected according to the fitting index with constraints.
- The proposed method is verified by the experiments, which can deal with dynamic interference.

ThPo6.3(17) 15:30–15:50
Distributed Entrapping Control of Multiple Second-order Mobile Agents Under a Directed Network
Min Deng, Xiao Yu, and Weiyao Lan
Department of Automation, Xiamen University, China

- The distributed entrapping control problem of the second-order multi-agent systems under a directed network.
- Time-varying entrapping formation has elasticity and rotation, whose parameter is only known to some agents.
- Distributed observer is used to estimate the formation shape parameter.
- A dynamic control law is proposed under the position and velocity measurements.
- Simulation example illustrates the theoretic result.

ThPo6.3(18) 15:30–15:50
Bionic Control Method for a Multi-Motor Joint Based on the Physiological Muscle Model
Liyan Chen, Sheng Bi, George Zhang, Shuju Qin*, Ning Xi
Shenzhen Academy of Robotics, China
Yong Zhang
National Astronomical Observatories / Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, China

- Bionic robots have recently displayed a promising prospect for broad applications.
- There is still a gap between the current progress and the biological feature resemblance of energy efficiency and natural compliance.
- This paper studies the bionic control method for a multi-motor joint based on the kinetics of biological muscle components and realizes the biological feature resembled motion.
ThC1: Motion Planning III
Session Chairs: Liwei Zhang and Yanding Qin
Room: Phoenix Ballroom, 1/F, 15:50-17:05, Thursday, December 30, 2021

ThC1(1) 15:50-16:05

Kinematic Analysis and Gait Planning of a Three-branch Relative Robot for On-orbit Assembly

Shengli Yang1, Deshan Meng1, Ping Jiang2, Wenqi Wan2, Zhiqiang Wu2
1. School of Aeronautics and Astronautics, Sun Yat-Sen University, Shenzhen
2. the Intropytech Co., Ltd.

- Modeling a three-branch relative robot for assembly
- The kinematics model and the inverse kinematics solution method are given
- The three-branch relative robot gait and the corresponding gait planning algorithm are defined
- Gait planning algorithms are verified by simulation and experiment

Three-branch Relative Robot Model

ThC1(2) 16:05-16:20

Time-Optimal Trajectory Planning for Robots with Identified Dynamics

Shize Lin, Ze Wang, Chuxiong Hu and Yu Zhu
Mechanical Engineering, Tsinghua University, China

- Time optimal trajectory planning of robots is formulated as an optimization problem utilizing identified dynamics
- Both jerk and torque limits are included as non-convex constraints
- The optimization is discretized and iteratively solved by sequential convex programming
- Real-world experiments are conducted on a 6-DOF industrial robot

Experimental setting

ThC1(3) 16:20-16:35

Synthesis and Online Re-planning Framework for Time-Constrained Behavior Tree

Chuanxiang Gao, Yu Zhai, and Ben M. Chen
Mechanical and Automation Engineering, The Chinese University of Hong Kong, Hong Kong
Biao Wang
Nanjing University of Aeronautics and Astronautics
Nanjing, Jiangsu, China

- Behavior Tree
- Time-Constrained
- Automatically Generate
- Online Re-plan

The scenario of search and rescue tasks with two UUVs.

ThC1(4) 16:35-16:50

A movement planning and control method of special robot over obstacle based on centroid monitoring

Yong Tao1,2,*, He Gao1, Yufang Wen1, Jiangbo Lan1
1. School of Mechanical Engineering & Automation, Beihang University, China
2. Research Institute of Aero-Engine, Beihang University, China

- Semi-autonomous obstacle climbing control
- The centroid kinematics model of the robot with variable structure.
- The non-line-of-sight obstacle height estimation method.
- The obstacle-climbing movement planning and control method

Simulation of robot climbing obstacles

ThC1(5) 16:50-17:05

Hybrid Frontier Detection Strategy for Autonomous Exploration in Multi-obstacles Environment

Guangjin Xu, Liwei Zhang, Ming Chen and Bingwei He

- Rapidly exploring Randon Tree (RRT) algorithms is widely used in path planning, while the RRT is inefficient for robotic exploration in large-scale environments with multi-obstacles and narrow corridors.
- Here, we propose a Hybrid Frontier Detection (HFD) strategy for autonomous exploration which incorporates a variable step-size random tree global frontier detector, a node-local random tree frontier detector, and a grid-based frontier detector algorithm.
- Compared with the traditional RRT-based strategy, the exploration time and traveling length of the proposed HFD strategy are respectively decreased by over 15% and 12% in the simulation environment and decreased by over 14% and 13% under the same experimental conditions in the experimental environment. The results indicate that the HFD strategy effectively solves the problem of autonomous exploration in the environment with multi-obstacles and narrow corridors.
**ThC2: Mechanism Design**

Session Chairs: Fei Wang and Xiao Liang

Room: Nan Shan A, 3/F, 15:50-17:05, Thursday, December 30, 2021

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**ThC2(1) 15:50–16:05**

**Mechanical Design of a Metamorphic Robot for High-voltage Transmission Line Insulator Detection**

Hui Yuan1,2,3, Bingbing Yuan2,3,4, Hongguang Wang2,3, Yifeng Song2,3

1 School of Mechanical Engineering and Automation, Northeastern University, Shenyang 110004, China
2 State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang 110016, China
3 Institutes for Robotics and Intelligent Manufacturing, Chinese Academy of Sciences, Shenyang 110169, China
4 University of Chinese Academy of Sciences, Beijing 100049, China

**Abstract**

An insulator detection metamorphic robot was designed for the insulator string on high-voltage transmission line. The configurations and static force analysis of the metamorphic clamping mechanism were analyzed. A prototype was developed to carry out trafficability, climbing performance and adaptability experiments. This experiment show that the insulator detection metamorphic robot has the advantages of lightweight, good adaptability, and compact structure.

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**ThC2(2) 16:05–16:20**

**Mechanism Design and Kinematic Analysis of a Robotic Modular Finger and Reconfigurable Hand**

Fei Wang, Duanling Li and Haiyuan Li

Beijing University of Posts and Telecommunications, China

**Abstract**

A fully driven finger and reconfigurable hand of a robot is designed. The kinematics of a single finger is analyzed and grasping workspace is obtained. The spring and the grasping range adjusting hole are integrated in the finger mechanism, resulting in simple structure, low production cost, and the adaptive grasping ability.

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**ThC2(3) 16:20–16:35**

**Design of a Gripper for Cable Assembly with Integrated In-hand Cable Manipulation Functions**

Yanling Zhou, Xin Jiang, Dayuan Chen, Yuhao Guo

Mechanical Engineering and Automation, Harbin Institute of Technology, Shenzhen, China

Yunhui Liu

Mechanical and Automation Engineering, The Chinese University of Hong Kong, China

**Abstract**

With functions for in-hand manipulating the cable segments, gripping, twisting and sliding the cable, Cable recognition.

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**ThC2(4) 16:35–16:50**

**Underactuated Picking Gripper for Grasping and Cutting Citrus**

Zhaojiang Yu, Jianjun Yuan, Dianzhen Guo, Liang Du, Sheng Bao

Shanghai Robotics Institute, Shanghai University, China

Shugen Ma

Department of Robotics, Faculty of Science and Engineering, Ritsumeikan University, Japan

**Abstract**

By designed the differential gear train enables the gripper to complete two actions by a motor. By designed an underactuated form requires no force sensor but completes a constant force control. By designed the RRSM, we can adjust the grip force according to the variety fruit.

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**ThC2(5) 16:50–17:05**

**High-precision end-tip positioning system for automatic interior finishing process based on laser level**

Dayuan Chen1, Yexi Chen1, Xin Jiang1 and Yunhui Liu2

1 Harbin Institute of Technology (Shenzhen), Shenzhen, Guangdong, China
2 Department of Mechanical and Automation Engineering, The Chinese University of Hong Kong, Hong Kong, China

**Abstract**

Proposed a high-accuracy, high-speed and low-cost positioning method for control the quality of interior finishing operation. Combined a customized end-effector to improve performance of putty applying. Designed a finding plane algorithm to adaptive the laser plane.
ThC3: Mobile Robots II
Session Chairs: Yang Gao and Hesheng Wang
Room: Nan Shan B, 3/F, 15:50-17:05, Thursday, December 30, 2021

ThC3(1) 15:50–16:05
Analysis on Ride Comfort of a Novel Eight Wheel Vehicle
Yu Zhang, Wenchuan Jia, Jianjun Yuan, Shugen Ma and Sheng Bao
School of Mechanometrics Engineering and Automation, Shanghai University, China
Shiqiang Wang, Sha He and Peihang Yu
Safety Environment Quality Surveillance and Inspection Research Institute, CNPC Chuanqing Drilling & Exploration, China

- Based on the proposed eight-wheel vehicle, the dynamic model of this vehicle is established.
- The simulations are carried out to discuss the factors affecting ride comfort.
- The ride comfort of the optimized eight-wheel vehicle has been significantly improved.

ThC3(2) 16:05–16:20
A Geometric Assistive Controller for the Users of Wheeled Mobile Robots without Desired States
Seyed Amir Tafreshi, Anklt A. Ravankar, Salazar Jose and Yasuhsia Hirata
Robotics Department, Tohoku University, Japan

- Developing a new Darboux-frame-kinematics on the frame of vehicle
- Proposing safety conditions and problem statement
- Developing the differential-geometry-based controller
- Analyzing the performance of the wheeled mobile robot behavior with and without assistive control

ThC3(3) 16:20–16:35
Stretchable Multi-modal Sensor using Capacitive Cloth for Soft Mobile Robot Passing through Gap
Takashi Takuma, Koki Haruno, Kosuke Yamada, Hidenobu Sumioka, Takashi Minato and Masahiro Shiomi

- Multi-modal soft sensor
  - made of silicone embedding a conductive fabric
  - gets higher capacitance not only in stretching but also object approaching
  - Soft robot driven by water
  - embeds the conductive fabric in silicone
  - estimates the shape of the obstacle through which the robot passes

ThC3(4) 16:35–16:50
A Visual SLAM Algorithm Based on Dynamic Feature Point Filtering
Sen Kang, Yang Gao, Kunpeng Li, Wangxin Cao
Chang'an University, Xi'an, China

- The purpose of this paper is to improve the positioning accuracy of the YOLOv4 Tiny target detection network in a dynamic environment
- YOLOv4 Tiny target detection network, perception dynamic objects
- LK optical flow method and Meanshift algorithm clusters velocities feature points
- The experimental results in the public dataset and real road environment show that the algorithm proposed can improve the positioning accuracy in a dynamic environment

ThC3(5) 16:50–17:05
Robot Navigation with Interaction-based Deep Reinforcement Learning
Yu Zhai and Yanzi Miao
School of information and control engineering, China University of mining and technology, China
Hesheng Wang
Department of Automation, Shanghai Jiao Tong University, China

- We propose a novel method base reinforcement learning of robot navigation called robot human interaction reinforcement learning (RHIRL)
- We propose a new environment representation method based attention mechanism which implicitly includes the potential interaction.
- Excellent navigation performance in dynamic and unfamiliar environment.
Automatic Recognition of Abdominal Organs in Ultrasound Images based on Deep Neural Networks and K-Nearest-Neighbor Classification

- A method for automatic recognition of abdominal organs in ultrasound images is proposed to make routine ultrasound imaging process easier and faster.
- We employ fine-tuned deep neural networks and PCA for feature extraction, and use a K-NN classifier to recognize the abdominal organs in the images.
- Experimental results show that with minimal training effort, our method can "lazily" recognize six abdominal organs from the ultrasound images in real time.

Zebrafishtracker: A multi-zebrafish tracking algorithm can effectively solve cross occlusion

- Zebrafishtracker can effectively solve the problem of cross occlusion in the tracking of multiple zebrafish.
- The instance segmentation and skeleton analysis strategies are used to improve the accuracy of crossover detection.
- 2D tracking of zebrafish is realized based on identity information. The results show that in two relatively complex videos, MOTa of our algorithm in the top-view reaches more than 95%.

Blurring Feature Analysis of Microscopic Images Based on Deep Learning

- We propose a blurring feature analysis system based on StyleGAN. The improved StyleGAN model was trained using the optimal VeOGAN in a Gaussian light source, and an ideal blurring image generation model based on StyleGAN was obtained.
- Through the automatic learning of the image features with dynamic primitives, a series of ideal blurring images of the optimal light source are generated and the blurring kernel of the optical imaging process is restored.
- A high-resolution image reconstruction method with respect to large-scale visible light images is proposed based on the extracted blurring kernel and the transfer-convolutional full-quadric splitting and convolutional preconditioned Richardson (DRDG-DRGD) neural network model.
Obstacle Avoidance Strategy of Improved APF Method in C-space
Jingshen Zhao and Ying Wang
School of Mechanical Engineering, Inner Mongolia University of Technology, China
Lixing Jin
School of Mechatronic Engineering, Beijing Institute of Technology, China

- This method is more compatible: the advanced improvements of the mobile robot APF method can be transplanted on C-APF.
- The calculation is brief.
- The trajectory calculated by C-APF is better.
- C-APF is more robust: this method is inclusive to the local minimum problem of workspace.

Formulation of Fault-tolerant Control for Hyper-redundant Multi-copters
Takuro Inohara
Graduate School of Frontier Sciences, The University of Tokyo, Japan
Keigo Watanabe and Isaku Nagai
Graduate School of Natural Science & Technology, Okayama University, Japan

- Hyper-redundant multi-copters are defined by generalizing the number of rotors on multi-copters
- Polycopters, a type of hyper-redundant multi-copters, is defined
- The PPNN and PPNP structures are introduced as the structures of aircrafts
- The PNPN structure is found to be superior from the viewpoints of fault-tolerance

Simultaneous Gait Generation and Path Following Control of Snake Robot Using MPC
Yichen Liang1, Chao Ren1, Yongchen Tang2, Xiaohan Li1 and Shugen Ma1,3
1) School of Electrical and Information Engineering, Tianjin University, Tianjin, China
2) Key Lab of Intelligent Data Information Processing and Control of Modern Process, Tangshan University, Tangshan, China
3) Department of Robotics, Ritsumeikan University, Shiga, Japan

1) The simultaneous gait generation and path following control with given forward velocity are investigated under the MPC scheme.
2) The cost function design in MPC is investigated for snake robot to realize the path following control and forward velocity maximization.
3) The forward velocity is controlled by viewing the desired velocity as one constraint.
4) Simulation results verify the effectiveness of the proposed control scheme.

Groove Profile Design and Durability Analysis of Sheave for Robotic Wire Climber System
Colin Pak Yu Chan, Keng Huat Koh, Kin Hei Shiu, Chun Ho So, Musthafa Farhan and King Wai Chiu Lai
Department of Biomedical Engineering, City University of Hong Kong, HKSAR
Kenny Pui Ching Yeung, Michelle Pui Yee Lau and Pak Kin Cheung
Customer Maintenance Service Department, The Hong Kong and China Gas Company Limited, HKSAR

- Design a robotic rope climber system for 40-storey building to perform the riser inspection operation
- Use Nylon sheave with novel V-grooved profile
- Obtain over 3.5 times of payload to weight ratio
- Sustain the rope-to-sheave traction after 1-km of travel distance
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CC: Session Chair
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