ICRA2017
May 29 – June 3, 2017 • Singapore

PROGRAM

May 29-June 3, 2017 • Singapore

**IEEE International Conference
on Robotics and Automation**

IEEE

IEEE Robotics & Automation Society

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WELCOME

Dear ICRA 2017 Attendees,

Welcome to Singapore! We are honoured to host you at the 2017 IEEE International Conference on Robotics and Automation (ICRA), held at the Marina Bay Sands International Convention Centre. ICRA 2017 will be filled with rich academic programs, exciting industry events, and multi-cultural social activities. Singapore is a cultural melting pot, and a garden city with a blend of old-world and new architecture. As a compact city, it is convenient to travel around the island. Hotels, restaurants, venues, shopping and sightseeing spots are conveniently clustered in various neighbourhoods, such as Marina Bay, Orchard Road, Changi, etc., and are easily accessible via Singapore's safe and reliable public transportation system. The Singapore Botanic Garden, a UNESCO World Heritage site, is a *must see* for visitors coming to Singapore.

It is timely that Singapore is hosting ICRA in 2017, as the country strives to be a *Smart Nation*, one where people are empowered by technology to lead meaningful and fulfilled lives, and to support better living, stronger communities, and create more opportunities for all. The conference theme, "**Innovation, Entrepreneurship, and Real-world Solutions**", underscores the need for innovative R&D talent, dynamic and goal-driven entrepreneurs and practitioners using robotics and automation technology to solve challenging real-world problems such as shortage of labor, an ageing society, and creating sustainable environments.

ICRA is the IEEE Robotics and Automation Society's flagship conference. This year we received 2289 paper submissions for technical program presentations, among which there are 1896 ICRA-direct submissions and 393 IEEE Robotics and Automation Letters (RA-L) submissions. All the submitted papers were peer-reviewed by either ICRA Conference Editorial Board or RA-L Editorial Board, and then recommended to the Senior Program Committee of ICRA2017 for final decision. Ultimately, 939 papers (749 ICRA-direct papers and 190 RA-L papers) are selected and included in the final program. The entire technical program is presented in the style of interactive sessions. We would like to welcome the proud authors of the papers in the technical program from 57 countries from around the world. There were also 38 workshop/tutorial proposal submissions, among which 23 full-day workshops and 2 half-day tutorials were selected and included in the final program, being peer-reviewed by the Workshop/Tutorial Committee.

The 5-day conference program includes workshops and tutorials spreading between the first and last day. On the other three days, the technical program consists of presentations of accepted papers, 3 plenary speeches and 6 keynote lectures given by world leading and outstanding speakers; accepted papers are presented in 118 interactive sessions in 11 parallel tracks. Each interactive session includes 5 to 8 papers. Each paper has a 5-minute spotlight introduction and subsequently a 35 ~ 50 minutes' interactive presentation with the audience staying in each session room. We hope that through such structured and in-depth interaction among authors and audience, exchange of ideas and comments can be carried out in a conducive manner.

In addition to interactive sessions, ICRA2017 also organizes a one-day track of special sessions on Emerging Robotics Technology with 13 prominent robotics experts to give their views on the development of future robotics. To promote IEEE Transactions on Robotics (TR-O), ICRA2017 for the first time in ICRA series introduces 3 oral presentation sessions organized by TR-O. The papers were recommended by TR-O Editorial Board from those accepted but not yet published in TR-O.

The technical program also includes Industry Forum, Government Forum, ASEAN and Emerging Economy Country Forum, and Ethics Forum. Under the theme of ICRA 2017, a new forum on Robotics Innovation and Entrepreneurship (RIE Forum) is organized. The RIE forum consists of 6 focused sessions with topics ranging from healthcare, logistics, manufacturing to education and social

robots. In each session, we invite 2 to 3 public and private lead-demand users talking about their needs in robotics and automation and several start-up companies to do pitch presentations on their solutions. A panel discussion among these presenters and jurors from robotics incubators and investment institutions will conclude each session.

In addition to a strong and timely technical program, ICRA 2017 has a vibrant and perhaps one of the largest industrial exhibition in ICRA, a Start-up corner for budding robotics entrepreneurs to showcase their innovative projects, and 4 Robotics Challenges addressing fundamental robotics technology and real-world deployment needs. Besides serving the professional robotics community, ICRA 2017 also expand the Public Outreach Forum ICRA-x on the last day of the technical presentations to invite the public, high school and polytechnic students to listen to world renown experts talking about different aspects of robotics to spur their interests in robotics.

One more innovation for ICRA 2017 is the introduction of tablet PC as the carrier of conference media. Each registered standard and student delegate will receive a 7" tablet PC installed with the conference program app and the entire conference proceedings including the papers and videos. ICRA 2017 will not distribute the hardcopy of the conference digest book in order to move towards a "paperless" conference in the future.

Time to socialize with colleagues and potential collaborators is also vital to a good conference, and ICRA 2017 provides plenty of opportunities. Our Welcome Reception at the Garden by the Bay will provide a unique experience to attendees to relax and social in the Flower Dome. The Conference Banquet at the Grand Ballroom of Marina Bay Convention Centre will showcase the delicate fine-dining experience of Singapore. The closing Farewell Reception at the Night Safari allows attendees to view the most unique night zoo in the world. These social events are in addition to the coffee breaks, lunch breaks, and the Awards Lunch at the Convention Centre.

Putting together an event like this requires a tremendous amount of volunteer effort. We are fortunate to have an outstanding Organizing Committee. Special recognition must go to the Conference Editorial Board (CEB) and the Editorial Board of Robotics and Automation Letters (EB-RA-L), which handled over 5000 reviews of the submitted papers. The technical expertise of the CEB and EB-RA-L was invaluable. The work of the Senior Program Committee who gathered in Singapore on 6-7 January 2017 and identified the very best contributions for ICRA 2017, needs to mention. We would like to take this opportunity to specially thank Dr. Allison Okamura, the Editor-in-Chief of the CEB and Dr. Antonio Bicchi, the Editor-in-Chief of the EB-RA-L, for their ethical, efficient, and professional handling of the entire review process, Dr. Chien Chern Cheah, Program Co-Chair, Dr. Shaohui Foong, the Local Chair and the entire local committee team, for taking care of the planning, logistics, and the tablet proceedings issues and making sure this ICRA will be the one to be proud of.

Last, but not the least, our sincere thanks go to all sponsors and exhibitors for their involvement and support and significant contribution to the overall success of ICRA 2017. We wish you an exciting conference week and we hope you will enjoy Singapore!

I-Ming Chen
ICRA 2017 General Chairman

Yoshihiko Nakamura
ICRA2017 Program Chairman

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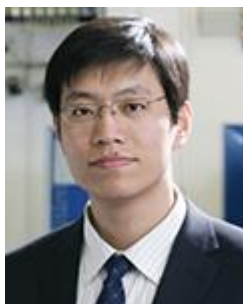
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- **National Robotics Programme, Singapore**
- **Jurong Town Corporation, Singapore**
- **Singapore Tourism Board**
- **Changi General Hospital, Singapore**
- **Center for Healthcare Assistive & Robotics Technology (CHART)
  - Changi General Hospital**

Exhibitors

The exhibition at ICRA 2017 includes a Start-up Corner, with product showcases and live demonstrations by some of the biggest names in the robotics and automation industry.
Venue: Grand Ballroom Foyer (Level 5)

Opening hours:

- May 30 (Tuesday): 08:00 – 17:00
- May 31 (Wednesday): 08:20 –17:00
- June 1 (Thursday): - 08:20 – 17:00

Meet these exhibitors and more at ICRA 2017:
- AAAS/Science, Robotics
- ABB
- Advanced Remanufacturing and Technology Centre (ARTC)
- Amazon Robotics
- ATI Industrial Automation
- Barrett Technology LLC
- Beijing Ewaybot Technology LLC
- BItcraze AB
- Cambridge University Press
- Clearpath Robotics
- Cruise Automation
- DJI
- ELID Technology International Pte Ltd
- Fetch Robotics
- Frontiers
- GT Robot Technology Pte Ltd
- Haption
- Hebi Robotics
- Hokuyo
- IEEE Robotics and Automation Society
- iniLabs, GmbH
- iRobot
- Instituto Italiano di Tecnologia
- JD.com
- JTC
- Kawasaki Heavy Industries, Ltd
- Khalifa University
- Kinova Robotics
- KNR Systems Inc.
- KUKA
- MathWorks
- Moog Inc.
- MUJIN
- OptiTrack
- Neuromeka
- Nihon Binary Co., Ltd
- Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Science
- New Energy and Industrial Technology Development Organization
- Nanyang Technological University
- Now Publishers

- nuTonomy
- PAL Robotics
- Perceptin
- Phoenix Technologies Inc.
- Preferred Networks
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- SAGE Publications Ltd
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- Shanghai Yikun Electrical Engineering Co. Ltd
- Smokie Robotics Inc
- Springer Nature
- ST Engineering
- Sunrise Instruments
- Tokyo Robotics Inc.
- Toyota Research Institute
- Uber Advanced Technologies Group
- UBTech
- UFACTORY
- Xbot Park

Start-up Corner
- Keyi Technology
- Robsense Technology
- Vitrus Inc.
- Transforma Robotics

Conference Events

Social Events

Monday, May 29th- Time: 1830 - 2100
Welcome Reception
Venue: Waterview Room & Flower Field Hall, Gardens by the Bay
Wednesday, May 31st- Time: 1900 - 2100
Conference Dinner (Banquet)
Venue: Grand Ballroom (Level 5), Sands Expo and Convention Centre
Thursday, June 1st- Time: 1900 - 2100
Farewell Reception
Venue: Night Safari (2-way transport provided from conference venue)

Forums and Special Events

Tuesday, May 30th
IEEE RAS Women in Engineering (WiE) Lunch
RIE Forum
Industry Forum
Special Sessions on Emerging Robotics technology
Wednesday, May 31st
IEEE RAS Lunch with Leaders(LwL) – for Students
IEEE RAS Young Professionals Luncheon
RIE Forum
Industry Forum
Government Forum
RAS Townhall Meeting
Thursday, May 19th
ASEAN & Emerging Country Forum
Ethics Forum
ICRA X Public Forum

Technical Tours

May 29, 2017 (Monday) – 13:00 to 16:00
Cost: SGD 20 per pax
Bus pick up at 12:30 from Marina Bay Sands and returns at 16:00.
- FANUC Tour

June 2, 2017 (Friday) – 09:00 to 17:00
Cost: SGD 60 per pax (lunch and leisure tour to Jurong Bird Park in the afternoon are included)
Bus pick up at 08:15 from Marina Bay Sands and returns at 17:00
- West Tour 1: Visit to NTU RRC, FANUC and Jurong Bird Park
- West Tour 2: Visit to SIMTech @ Valley Block, ARTC, FANUC and Jurong Bird Park
- West Tour 3 : Visit to ST Engineering-NTU Corporate Lab, FANUC and Jurong Bird Park
- Central Tour 1: Visit to I^{2}R, SIMTech @ Fusionpolis 2 and Jurong Bird Park
- Central Tour 2: Visit to NUS ARC, HOPE Technik and Jurong Bird Park
- East Tour: Visit to CHART, SUTD and Jurong Bird Park

RAS Events

RAS is pleased to arrange three Luncheon Networking events for our members attending ICRA 2017 in Singapore. Please tick the relevant boxes on the <u>conference registration form</u> if you wish to attend the luncheon(s). As space is limited for these popular events, please register early to avoid disappointment.

RAS Women In Engineering (WIE) Luncheon
Tuesday - May 30, 2017
Time: 1245 - 1345
Venue: Sands N (Level 5, next to Grand Ballroom)
Capacity: 90 seats
The luncheon provides the opportunity to foster discussion on the role of women in robotics and automation, inspire girls and promote collaborations and initiatives to advance women in leadership. As the goal for this event is to be more than a lunch for women, but a lunch with women, men are more than welcome to participate and enjoy the discussion.

RAS Lunch with Leaders (LwL) – for Students
Wednesday - May 31, 2017
Time: 1330 - 1430
Venue: Sands N or O (Level 5, next to Grand Ballroom)
Capacity: 90 seats
This luncheon is open to student attendees, offering the chance to meet and interact with leaders from RAS. Details to follow.

Young Professionals Luncheon
Wednesday - May 31, 2017
Time: 1330 - 1430
Venue: Sands O (Level 5, next to Grand Ballroom)
Capacity: 110 seats
Under the umbrella of IEEE Young Professionals program, the Robotics & Automation Society (RAS) is further empowering its young professionals through the RAS Young Professionals (YP) group. 'Young Professionals' are IEEE members who have graduated with their first professional degree within the last 15 years, and who are not student members.

RAS Town Hall
Wednesday - May 31, 2017
Time: 16:05 – 17:20
Venue: 4211/4212 (Level 4)
Calling all members of the IoEEE Robotics & Automation Society, and those interested in learning more about our journals, current and future topics, participation as a Reviewer, Author or Editor. Meet your RAS Leadership, and those involved in RAS Publication Business. Get your questions answered and learn how you may be able to engage and contribute further to the RAS Publication Community.
Topic: **RAS Publications**

- State of the Society - **Satoshi Tadokoro**, RAS President
- RA-L - **Antonio Bicchi, Editor in Chief**, *IEEE Robotics & Automation Letters*
- PRAC review (T-RO, T-ASE, RAM) - **Eugenio Guglielmelli**, RAS VP Publication Activities Board
- Code Ocean - **Simon Adar**
- Future Plans for RAS Publications
- Q&A

Social Events

Tickets to the ICRA 2017 social events are included in the **Standard** and **Student** conference packages, and **Accompanying Guest** tickets. Additional tickets to the Conference Dinner (on May 31) can be purchased for SGD 175.

Monday - May 29, 2017- Time: 1830 - 2100

Welcome Reception

Venue: Waterview Room & Flower Field Hall, Gardens by the Bay
(Walking route from conference venue to Flower Dome)

Connected to the conference venue via an overhead bridge (Lions Bridge), Gardens by the Bay is a sprawling garden in the city spanning 101 hectares of reclaimed land and home to two cooled conservatories. One of them, the Flower Dome, will be the venue for the ICRA 2017 Welcome Reception. The Flower Field Hall and Waterview Room are nestled within the Flower Dome, offering a stunning backdrop of perpetual spring with full views of the splendid Flower Field on one side and a spectacular panorama of the Marina Bay skyline on the other.

Wednesday - May 31, 2017- Time: 1900 - 2100

Conference Dinner (Banquet)

Venue: Grand Ballroom (Level 5), Sands Expo and Convention Centre

The ICRA 2017 Conference Dinner will be held at the <u>conference venue</u> itself, in the Grand Ballroom –Southeast Asia's biggest ballroom. The banquet will be an excellent opportunity for delegates to mingle and network with fellow delegates from around the world.

Thursday - June 1, 2017- Time: 1900 - 2100

Farewell Reception

Venue: Night Safari (2-way transport provided from conference venue)

As dusk falls, get ready as over 1,000 animals start their nightly rituals. Come up close to them as they frolic, graze and hunt. With an exciting tram ride that takes you through six geographical regions, four interlinked walking trails and more, embark on a fascinating journey through the world's very first nocturnal wildlife park – the <u>Night Safari</u>. ICRA 2017 Farewell Reception tickets are inclusive of admission to Night Safari and the tram ride.

Technical Program

Conference Schedule

MONDAY May 29, 2017	TUESDAY May 30, 2017						WEDNESDAY May 31, 2017							THURSDAY June 1, 2017					FRIDAY June 2, 2017		SATURDAY June 3, 2017
	Opening Ceremony																				
	Plenary						Plenary							Plenary							
Workshop/Tutorial Sessions	Technical Sessions	Special Session	Industry Forum	RIE Forum			Technical Sessions	Poster Session	Gov't Forum	Industry Forum	RIE Forum			Technical Sessions	ASEAN Forum	ICRA-X (Public Forum)			Workshop/Tutorial Sessions		RAS Adcom Meeting
Coffee Break	Coffee Break						Coffee Break							Coffee Break					Coffee Break		
Workshop/Tutorial Sessions	Technical Sessions	Special Session	Industry Forum	RIE Forum			Technical Sessions	Poster Session	Gov't Forum	Industry Forum	RIE Forum			Technical Sessions	ASEAN Forum	ICRA-X (Public Forum)			Workshop/Tutorial Sessions		
	Lunch Break				Robot Challenges	Exhibition & Start-up Corner	Keynote					Robot Challenges	Exhibition & Start-up Corner	Award Lunch (Foyer & Grand Ballroom)			Robot Challenges	Exhibition & Start-up Corner		Technical & Leisure Tours	
Lunch Break	Keynote						Keynote												Lunch Break		
	Keynote						Lunch Break							Keynote							
Workshop/Tutorial Sessions	Technical Sessions	Special Session	Industry Forum	RIE Forum			Technical Sessions	Poster Session	Gov't Forum					Keynote					Workshop/Tutorial Sessions		
Coffee Break	Coffee Break						Coffee Break							Coffee Break					Coffee Break		
Workshop/Tutorial Sessions	Technical Sessions	Special Session	Industry Forum	RIE Forum			Technical Sessions	Poster Session	RAS Townhall Meeting					Technical Sessions	Ethics Forum				Workshop/Tutorial Sessions		
Welcome Reception (Gardens By the Bay)							Conference Banquet							Farewell Reception (Night Safari)							

(Column labels also appearing vertically: Technical Tours — Monday; Robot Challenges — Tuesday/Wednesday/Thursday; Exhibition & Start-up Corner — Tuesday/Wednesday/Thursday; Technical & Leisure Tours — Friday)

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Floor Plans
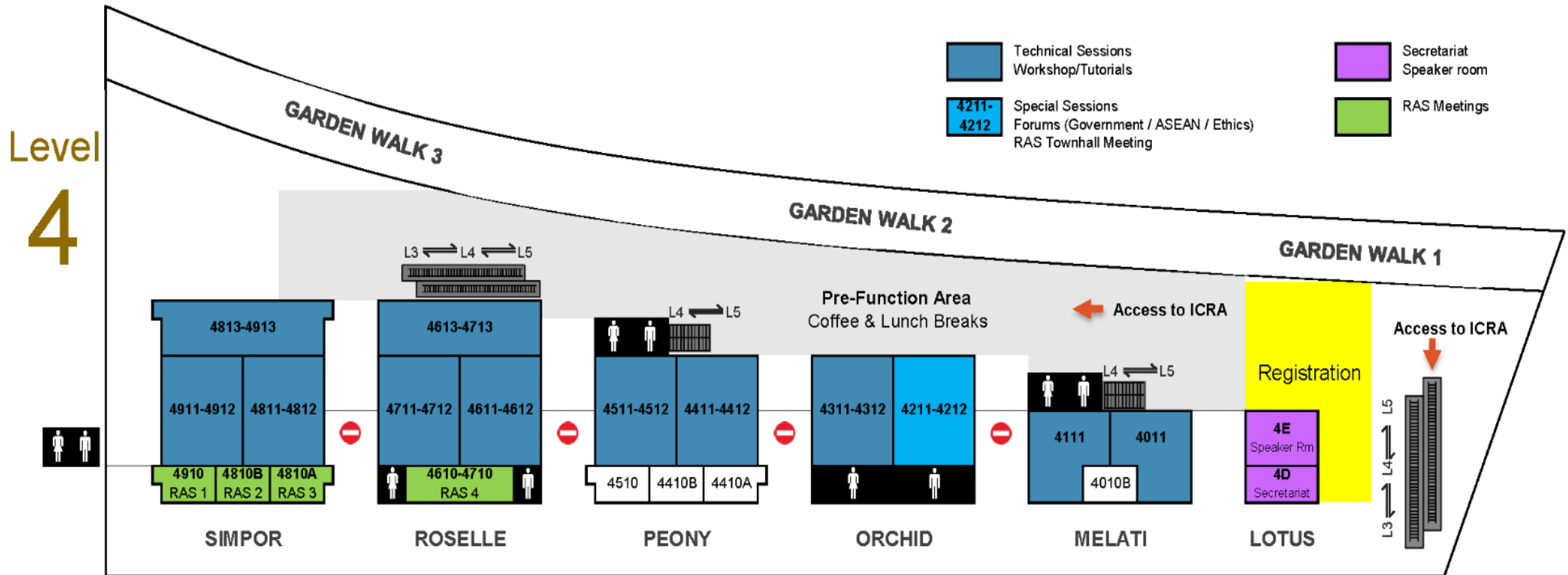
Accurate as of April 13, 2017 and subject to changes

Level 5

Robot Challenges

L3 ⇄ L4 ⇄ L5

L4 ⇄ L5

L4 ⇄ L5

5301	5201
5302	**5202** HRATC

Grand Ballroom Foyer
Coffee & Lunch Breaks
Poster Sessions

Exhibition & Start-up Corner

L3 ⇄ L4 ⇄ L5

Kitchen

Sands N
Industry Forum
RAS Lunch

Sands O
RIE Forum
RAS Lunch

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Grand Ballroom
Opening Ceremony
Plenary & Keynotes
Conference Banquet
Award Ceremony
ICRA-X

5101-5103 SMRC MMC

5001-5003 DJI RoboMasters Challenge
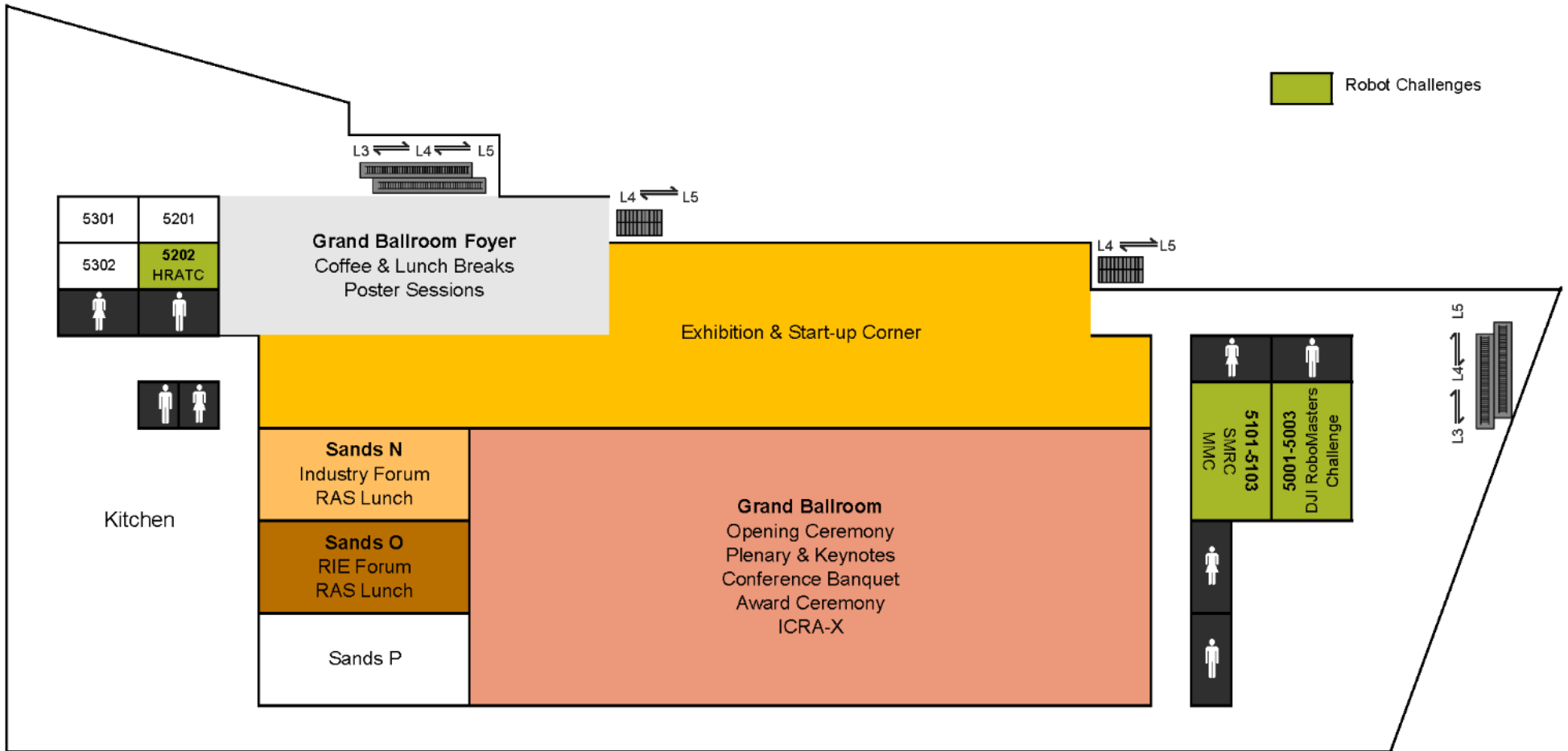
Accurate as of April 13, 2017 and subject to changes

Plenary and Keynote Talks

Tuesday - May 30, 2017 *Grand Ballroom (Level 5)*

08:45–
09:45
PLENARY 1
Modeling the possibilities: From the Chalkboard to the Race Track to the World Beyond
Chris Gerdes, Stanford University, USA

13:45–
14:15
KEYNOTE 1
EndoMaster: A Surgical Robot's Journey from the Research Lab to the Operating Theatre
Louis Phee, Nanyang Technological University, Singapore

14:15–
14:45
KEYNOTE 2
Capturing Vivid 3D Models of the World from Video
Lourdes Agapito, University College London, UK

Wednesday - May 31, 2017 *Grand Ballroom (Level 5)*

08:20–
09:20
PLENARY 2
Nobel Turing Challenge: Grand Challenge of AI, Robotics, and Systems Biology
Hiroaki Kitano, Sony Computer Science Laboratories, Inc., Japan

12:30–
13:00
KEYNOTE 3
Industry 4.0 – Automation and Robotics
Peter Luh, University of Connecticut, US

13:00–
13:30
KEYNOTE 4
Research at the Intersection Between Robots and Play: Designing Robots for Children's Healthcare
Ayanna Howard, Georgia Tech, USA

Thursday - June 1, 2017 *Grand Ballroom (Level 5)*

08:20–
09:20
PLENARY 3
Framing the International Discussion on the Weaponization of Increasingly Autonomous Technologies
Kerstin Vignard, United Nations Institute for Disarmament Research

14:50–
15:20
KEYNOTE 5
An Operational Platform of Cloud Robotics
Bill Huang, Cloud Minds, China

15:20–
15:50
KEYNOTE 6
Model-based Optimization for Humanoid and Wearable Robots
Katja Mombaur, University of Heidelberg, Germany

Plenary 1

08:45– 09:45, Tuesday - May 30 (Grand Ballroom)

Modeling the possibilities: From the Chalkboard to the Race Track to the World Beyond

Chris Gerdes

Stanford University, USA

Simple mathematical models of physical systems give us tremendous insight into the nature of their underlying dynamics and the control challenges they present. Stripping away unnecessary details can illuminate fundamental dependencies and focus engineering efforts on the most critical problems. The challenge comes when models become so familiar that they are no longer taken as simplifications but mistaken for reality itself. Opportunities and possibilities that lie outside the bounds of those simple models are subsequently missed.

Ground vehicle dynamics represent an ideal illustration of these principles. While vehicles are complex multi-body systems with uncertain and nonlinear dynamic properties due to tire mechanics, many simplifications of these dynamics exist. By choosing the right level of abstraction for a model, anything from parallel parking to a race car driver's choice of trajectory to drifting with smoking rear tires can be explained clearly and concisely. The choice of model is important, however, since what one model illuminates, another may obscure. This talk demonstrates through mathematics and video from experiments how simple models can be used to accurately control automated vehicles through even the most extreme maneuvers on the race track. Lap times comparable to expert drivers and drifting maneuvers beyond the precision of a human are possible with models consisting of only a few state variables.

Just as models can guide or limit us in our work as researchers and engineers, our models of what it means to be a researcher or academic can sometimes artificially limit our impact in the world. The talk concludes with some simple models of how the robotics community can provide necessary leadership and technical guidance as society wrestles with the changes arising from our technologies.

Bio: **Chris Gerdes** is a Professor of Mechanical Engineering and, by courtesy, of Aeronautics and Astronautics at Stanford University. His laboratory studies how cars move, how humans drive cars and how to design future cars that work cooperatively with the driver or drive themselves. When not teaching on campus, he can often be found at the racetrack with students, instrumenting historic race cars or trying out their latest prototypes for the future. Vehicles in the lab include X1, an entirely student-built test vehicle; Shelley, an automated Audi TT-S that can lap a racetrack as quickly as an expert driver; and MARTY, an electrified DeLorean capable of controlled drifts. Chris and his team have been recognized with a number of awards including the Presidential Early Career Award for Scientists and Engineers, the Ralph Teetor award from SAE International and the Rudolf Kalman Award from the American Society of Mechanical Engineers.

From February 2016 to January 2017, Chris served as the first Chief Innovation Officer at the United States Department of Transportation. In this role, he worked with Secretary Anthony Foxx to foster the culture of innovation across the department and find ways to support transportation innovation taking place both inside and outside of government. He was part of the team that developed the Federal Automated Vehicles Policy and represented the Department on the National Science and Technology Committee Subcommittee on Machine Learning and Artificial Intelligence. He continues to serve U.S. DOT as Vice Chair of the Federal Advisory Committee on Automation in Transportation.

Chris is a co-founder of truck platooning company Peloton Technology and served as Peloton's Principal Scientist before joining U.S. DOT.

Plenary 2

08:20 – 09:20, Wednesday - May 31 (Grand Ballroom)

Nobel Turing Challenge: Grand Challenge of AI, Robotics, and Systems Biology

Hiroaki Kitano

Sony Computer Science Laboratories, Inc., Japan

Nobel Turing Challenge is one of the ultimate challenges the scientific community can tackle. It aims at (1) developing AI system including substantial robotics components that can make major scientific discoveries some of which worth Nobel Prize (called as "Scientific Discovery Challenge"), and (2) actually win the prize without the selection committee noticed that it is actually an AI system, not a human researcher (Cybernetic Personality Challenge). Primary focus on this challenge will be biomedical science area for Physiology and Medicine Award (Kitano, H., *AI Magazine*, 37(1) 2016).

This grand challenge project shall take a form of globally distributed "Virtual Big Science" project (Kitano, H., et al., *Nature Chemical Biology*, 7, 323-326, 2011). A part of the project shall resemble RoboCup (Kitano, H., et al., *AI Magazine*, 18(1) 73-85, 1997), but it will have substantially different aspects reflecting the difference of domains and objectives.

In the mid 90s, I advocated "Systems Biology" with the aim of promoting systems-oriented view in biology and to introduce more systematic measurements, proper applications of engineering, mathematical, and information science principles into life science (Kitano, H., *Science*, 295, 1662-1664, 2002; Kitano, H., *Nature*, 420, 206-210, 2002). This endeavor has been successful and systems biology is one of normal approach in biomedical and pharmaceutical sciences. The progress in systems biology revealed new limitations in life science that stems from our cognitive limitations to understand complex, non-linear, high dimensional, and dynamical systems, with overwhelming data and publications each of which unveils only a fragment of systems.

With recent breakthroughs in AI, exponentially increasing data production capabilities, and massive computing power, disruptive innovations in biomedical sciences are on the horizon. Time is ripe to embark on a new aggressive challenge. The fundamental breakthrough will come at the stage AI to generate hypotheses and quickly verify them using their knowledge bases, simulation, and robotics experimental systems. It means that AI systems can keep discovering new knowledge with minimal or zero human interventions. Even a mid-term achievement of Scientific Discovery Challenge alone will be a game changer. It will trigger fundamental transformations of industry and more largely on the shape of our civilization.

Bio: **Hiroaki Kitano** is President and CEO at Sony Computer Science Laboratories, Inc., Corporate Executive at Sony Corporation, President at The Systems Biology Institute, Tokyo, Professor at Okinawa Institute of Science and Technology Graduate University, Okinawa, and Director at Laboratory for Disease Systems Modeling, RIKEN Center for Integrative Medical Sciences, Kanagawa, and a member of AI and Robotics Council of the World Economic Forum. He received a B.A. in physics from the International Christian University, Tokyo, and a Ph.D. in computer science from Kyoto University. Since 1988, he has been a visiting researcher at the Center for Machine Translation at Carnegie Mellon University. His research career includes

a Project Director at Kitano Symbiotic Systems Project, ERATO, Japan Science and Technology Corporation followed by a Project Director at Kitano Symbiotic Systems Project, ERATO-SORST, Japan Science and Technology Agency where numbers of spin-offs were created including ZMP Inc., iXs Research, RT Coporation, Flower Robotics Inc., Xiborg Inc., etc.

Kitano is a Founding President of The RoboCup Federation, a founder and president of International Society for Systems Biology (ISSB), and an Editor-in-Chief of Nature Partner Journal (npj) Systems Biology and Applications. He served as a president of International Joint Conference on Artificial Intelligence (IJCAI) during 2011-2013. Kitano received The Computers and Thought Award from the International Joint Conferences on Artificial Intelligence in 1993, Prix Ars Electronica 2000, and Nature Award for Creative Mentoring in Science 2009, as well as being an invited artist for Biennale di Venezia 2000 and Museum of Modern Art (MoMA) New York in 2001.

Plenary 3

08:20 – 09:20, Thursday - June 1 (Grand Ballroom)

Framing the International Discussion on the Weaponization of Increasingly Autonomous Technologies

Kerstin Vignard

United Nations Institute for Disarmament Research

There are a multitude of positive military applications for increasingly autonomous technologies. However, their potential weaponization raises a host of legal, technical, operational and ethical questions. Since 2013, member states of the United Nations have been discussing the weaponization of increasingly autonomous technologies (Lethal Autonomous Robots, Lethal Autonomous Weapon Systems, or so-called "killer robots") in both human rights and arms control fora. Four years in, there is still great division on definitions, how to ensure human control over these future weapon systems, and the appropriate policy responses. These political discussions are held in the near absence of the technical community. As the rate of technological innovation far outpaces the policy discussion, how might engagement with the technical experts enable international policy-makers to better think, discuss and make informed decisions about increasing autonomy in weapon systems?

***Bio*: Kerstin Vignard**, a dual US-French national, is an international security policy professional with over 20 years' experience at the United Nations. As Deputy Director and Chief of Operations at the UN Institute for Disarmament Research, she advises the Director on strategic direction and oversees all activities of the Institute.

Since 2013, she has led UNIDIR's work on the weaponization of increasingly autonomous technologies, which has focused on advancing the multilateral discussion on weaponized autonomy by refining the areas of concern, identifying relevant linkages, and learning from approaches from other domains, including the private sector, that may be of relevance. This work has provided insights and conceptual frameworks to enable international policy-makers to better think, discuss and make informed decisions about autonomy in weapon systems, for example within the framework of the Convention on Certain Conventional Weapons and the UN Human Rights Council. In addition, Vignard has served as consultant to four UN Groups of Governmental Experts on cyber warfare.

Keynote 1

13:45– 14:15, Tuesday - May 30 (Grand Ballroom)

EndoMaster: A Surgical Robot's Journey from the Research Lab to the Operating Theatre

Louis Phee

Nanyang Technological University, Singapore

I will share my experiences in developing a novel flexible robotic system that removes gastric and colon tumours using natural orifices as points of access. I will discuss the technical and medical challenges faced to push the research to successfully test the robot on human subjects. Thereafter, a company (EndoMaster) was incorporated to commercialise the product. The challenges faced in the translation of the robotic technology to be used in a clinical setting were entirely different from the research phase. By sharing my experiences, I hope to inspire more researchers to translate their research and inventions to actual useful products.

Bio: **Dr Louis Phee** is a Professor at Nanyang Technological University (NTU), Singapore. He is Chair of the School of Mechanical & Aerospace Engineering at NTU. He graduated from NTU with the B.Eng (Hons) and M.Eng degrees in 1996 and 1999 respectively. He obtained his PhD from Scuola Superiore Sant'Anna, Pisa, Italy in 2002 on a European Union scholarship. His research interests include Medical Robotics and Mechatronics in Medicine. He was the founding CEO of EndoMaster Pte Ltd, a company he co-founded to commercialize a surgical robotic system he developed.

Dr Phee was awarded the Young Scientist Award (2006), the Outstanding Young Persons of Singapore Award (2007), the Nanyang Outstanding Young Alumni Award (2011), Nanyang Innovation and Entrepreneurship Award (2013) and the President's Technology Award (2012). In 2005, he was awarded the Best Paper Award at the prestigious IEEE International Conference on Robotics and Automation.

Keynote 2

14:15– 14:45, Tuesday - May 30 (Grand Ballroom)

Capturing Vivid 3D Models of the World from Video

Lourdes Agapito

University College London, UK

As humans we take the ability to perceive the dynamic world around us in three dimensions for granted. From an early age we can grasp an object by adapting our fingers to its 3D shape; we can understand our mother's feelings by interpreting her facial expressions; or we can effortlessly navigate through a busy street. All of these tasks require some internal 3D representation of shape, deformations and motion.

Building algorithms that can emulate this level of human 3D perception has proved to be a much harder task. In this session, I will show progress from early systems which captured sparse

3D models with primitive representations of deformation towards the most recent algorithms which can capture every fold and detail of hands or faces in 3D using as input video sequences taken with a single consumer camera. There is now great short-term potential for commercial uptake of this technology, and I will show applications to robotics, augmented and virtual reality and minimally invasive surgery.

Bio: **Professor Lourdes Agapito** obtained her BSc, MSc and PhD (1996) degrees from the Universidad Complutense de Madrid (Spain). She held an EU Marie Curie Postdoctoral Fellowship at The University of Oxford's Robotics Research Group before being appointed as a Lecturer at Queen Mary, University of London in 2001. In 2008 she was awarded an ERC Starting Grant to carry out research on the estimation of 3D models of non-rigid surfaces from monocular video sequences. In July 2013 she joined the Department of Computer Science at University College London (UCL) as a Reader where she leads a research team that focuses on 3D dynamic scene understanding from video and became full Professor of 3D Computer Vision in 2015.

Lourdes was Program Chair for CVPR 2016, the top annual conference in computer vision; in addition she was Programme Chair for 3DV'14 and Area Chair for CVPR'14, ECCV'14, ACCV'14 and Workshops Chair for ECCV'14. She has been keynote speaker for CVMP'15 and for several workshops associated with the main computer vision conferences (ICCV, CVPR and ECCV). Lourdes is Associate Editor for IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI) and the International Journal of Computer Vision (IJCV), a member of the Executive Committee of the British Machine Vision Association and a member of the EPSRC Peer Review College.

Keynote 3

12:30– 13:00, Wednesday - May 31 (Grand Ballroom)

Industry 4.0 – Automation and Robotics

Peter Luh

University of Connecticut, US

Industry 4.0 is a confluence of trends and technologies pushed by the digital revolution and the "Internet of Things" and driven by customer demand for high quality and customized products at reasonable prices. With the ubiquitous connection and interaction of machines, things and people, including customers, the ways we design and manufacture products and provide services will be fundamentally changed.

In this talk, Industry 4.0 will be introduced from the perspective of automation and robotics, including design principles and key technologies. An important but difficult technology often missing in discussions – mathematical optimization, will be highlighted. Applications to Clean Energy Smart Manufacturing will be illustrated. Implications on robotics will be discussed. Industry 4.0 in the USA, Europe, China and Japan will also be introduced.

Bio: **Peter B. Luh** received his B.S. from National Taiwan University, M.S. from M.I.T., and Ph.D. from Harvard University. He has been with the University of Connecticut since 1980, and currently is the SNET Professor of Communications & Information Technologies. He is also a member of the Chair Professors Group, Center for Intelligent and Networked Systems (CFINS) in the Department of Automation, Tsinghua University, Beijing, China.

Professor Luh is a Fellow of IEEE, and a member of IEEE TAB Periodicals Committee. He was the VP of Publications of RAS (2008-2011), the founding Editor-in-Chief of the IEEE Transactions on Automation Science and Engineering (2003-2007), and the Editor-in-Chief of

IEEE Transactions on Robotics and Automation (1999-2003). His research interests include intelligent manufacturing systems, smart power systems, and smart and green buildings. He received IEEE Robotics and Automation Society (RAS) 2013 Pioneer Award for his pioneering contributions to the development of near-optimal and efficient planning, scheduling, and coordination methodologies for manufacturing and power systems. He is the 2017 recipient of the RAS George Saridis Leadership Award for his exceptional vision and leadership in strengthening and advancing Automation in the RAS.

Keynote 4

13:00– 13:30, Wednesday - May 31 (Grand Ballroom)

Research at the Intersection Between Robots and Play: Designing Robots for Children's Healthcare

Ayanna Howard

Georgia Tech, USA

There are an estimated 150 million children worldwide living with a disability. For many of these children, physical therapy is provided as an intervention mechanism to support the child's academic, developmental, and functional goals from birth and beyond. With the recent advances in robotics, therapeutic intervention protocols using robots is now ideally positioned to make an impact in this domain. There are numerous challenges though that still must be addressed to enable successful interaction between patients, clinicians, and robots - developing interfaces for clinicians to communicate with their robot counterparts; developing learning methods to endow robots with the ability to playfully interact with the child; and ensuring that the robot can provide feedback to the parent and clinician in a trustworthy manner.

I will discuss the role of robotics and related technologies for pediatric therapy and highlight our methods that bring us closer to this goal. I will present our approaches and preclinical studies in which these technologies address real-life developmental goals for children with special needs.

Bio: **Ayanna Howard,** Ph.D. is Professor and Linda J. and Mark C. Smith Endowed Chair in Bioengineering in the School of Electrical and Computer Engineering at the Georgia Institute of Technology. She also holds the position of Associate Chair for Faculty Development in ECE. She received her B.S. in Engineering from Brown University, her M.S.E.E. from the University of Southern California, and her Ph.D. in Electrical Engineering from the University of Southern California.

Her area of research is centered around the concept of humanized intelligence, the process of embedding human cognitive capability into the control path of autonomous systems. This work, which addresses issues of autonomous control as well as aspects of interaction with humans and the surrounding environment, has resulted in over 200 peer-reviewed publications in a number of projects – from scientific rover navigation in glacier environments to assistive robots for the home. To date, her unique accomplishments have been highlighted through a number of awards and articles, including highlights in *USA Today*, *Upscale*, and *TIME Magazine*, as well as being named a *MIT Technology Review* top young innovator and recognized as one of the 23 most powerful women engineers in the world by *Business Insider*.

In 2013, she also founded Zyrobotics, which is currently licensing technology derived from her research and has released their first suite of therapy and educational products for children with

differing needs. From 1993-2005, Dr. Howard was at NASA's Jet Propulsion Laboratory, California Institute of Technology. She has also served a term as the Associate Director of Research for the Georgia Tech Institute for Robotics and Intelligent Machines and a term as Chair of the multidisciplinary Robotics Ph.D. program at Georgia Tech.

Keynote 5

14:50– 15:20, Thursday - June 1 (Grand Ballroom)

An Operational Platform of Cloud Robotics

Bill Huang

Cloud Minds, China

Cloud Robotics is a kind of robot whose "brains" are on cloud, with a global high-speed backbone network as the "nerve". In the near future, all the intelligent robots will be Cloud Robotics. At this session, we will introduce the architecture of Cloud Robotics, and how to build an operational platform for millions of robots with human assistant robot intelligence, mobile intranet cloud services, and robot control units.

Bio: **Bill Huang** is Founder and CEO of CloudMinds Inc. Before Cloudminds, he was GM of China Mobile Research Institute, SVP and CTO of UTStarcom, and previously worked at AT&T Bell Labs. Bill has creatively proposed the soft-switch concept of "the Network is the Switch", developed the first mobile soft-switch system in the world, and developed the first carrier-class streaming media exchange and IPTV system. He proposed the strategic concept of constructing the three major infrastructures (network, applications and terminals) of the next-generation mobile internet for the carriers, and promoted TD-LTE to be an internationally mainstream B3G standard, thus raising the technological influence of China in the communications industry.
In 2016, Bill was honoured IEEE CQR award. Besides, He is one of the first group of "Talent 1000" plan of China, a professor of University of Electronic Science and Technology of China, and a board member of GPS International Advisory Board of UC San Diego.
Bill received his master degree in Electrical Engineering and Computer Science from the University of Illinois in 1984. He graduated from the Huazhong University of Science and Technology in 1982 with a bachelor degree in Electrical Engineering.

Keynote 6

15:20– 15:50, Thursday - June 1 (Grand Ballroom)

Model-based Optimization for Humanoid and Wearable Robots

Katja Mombaur

University of Heidelberg, Germany

In this talk, I give an overview of our research on motion optimization for humanoid and wearable robots. On the one hand, we are interested to improve the walking capabilities of humanoid robots in different terrains. Optimization based on

realistic mechanical models of the robots is a very helpful tool since it can generate motions for such redundant, underactuated systems with multiple degrees of freedom and changing contacts that are feasible, stable and optimal. Optimization can also be applied to compliant robots.

On the other hand, we are interested to improve the design and control of wearable robots for the lower limbs and the lower back and other assistive devices. Using combined models of humans and the devices and optimal control, we can predict human movement in different conditions and determine the best possible support actions selecting passive and active components.

One important approach for both research fields is the solution of inverse optimal control problems based on recorded motion data which allows to identify objective functions underlying human movement. These optimality criteria can then be transferred to humanoid robots or be used for human movement prediction. For both fields, I will discuss the modeling levels to be used for describing humans and robots to address specific research questions. In addition, I will discuss possible combinations of optimal control methods with reinforcement learning and movement primitive approaches to reduce computation times and improve robot control.

***Bio*: Katja Mombaur** is a full professor at the Institute of Computer Engineering (ZITI) of Heidelberg University and head of the Optimization in Robotics & Biomechanics (ORB) group as well as the Robotics Lab. She holds a diploma degree in Aerospace Engineering from the University of Stuttgart and a Ph.D. degree in Mathematics from Heidelberg University. She was a postdoctoral researcher in the Robotics Lab at Seoul National University, South Korea. She also spent two years as a visiting researcher in the Robotics department of LAAS-CNRS in Toulouse.

Katja is the coordinator of the newly founded Heidelberg Center for Motion Research. She also is PI in the European H2020 project SPEXOR and the Graduate School HGS MathComp as well as in several national projects. Until recently, she has coordinated the EU FP7 project KoroiBot and was PI in the EU projects MOBOT and ECHORD–GOP. She is founding chair of the IEEE RAS technical committee Model-based optimization for robotics.

Special Sessions on Emerging Robotics Technology

Sponsored by National Robotics Programme, Singapore

First introduced in 1921, "robota" (robots), which means "labours" for humans, have served their purpose well in automobile manufacturing industry. For many years, scientists have been focusing on expanding the use of robot beyond those safety cages into other applications where human and robots can work together seamlessly.

This year, ICRA 2017 is honored to invite prominent robot experts to share the recent technological advancement in the field of robotics. These special sessions will focus on novel and creative approaches in designing or developing robots for automation, medical or surgical tasks, and space exploratory mission.

Tuesday - May 30, 2017

Venue: Room 4211/4212 (Level 4)

TIME	SESSIONS
0955 – 1110	**SESSION 1** **Intelligent Manufacturing and Automation** Chair: **Marcelo Ang**, National University of Singapore, Singapore
0955 – 1020	**Alternative Sensing and Perception based on Physical fields for Robotics and Automation** **Kok-Meng Lee**, Georgia Institute of Technology, USA
1020 – 1045	**Title TBC** **Nancy Amato**, Texas A&M University, USA
1045 – 1110	**Robotic Machining: Challenges and Chances** **Han Ding**, Huazhong University of Science & Technology, China
1110 – 1130	*AM Break – L4 Pre-Function Area*
1130 – 1245	**SESSION 2** **Medical and Micro Robotics** Chair: **Dong-Soo Kwon**, Korea Advanced Institute of Science and Technology (KAIST), Korea
1130 – 1155	**Recovery of Function in Major Spinal Cord Injury Using Spinal Stimulation and Assistive Robotics** **Joel Burdick**, California Institute of Technology, USA
1155 – 1220	**Micro Medical Robotics: Painless and Scarless** **Max Meng**, The Chinese University of Hong Kong, China
1220 – 1245	**Opportunities at the Bottom** **Bradley Nelson**, EidgenössischeTechnische Hochschule (ETH) Zürich, Switzerland
1245 – 1345	*Lunch – L4 Pre-Function Area*
1445 – 1600	**SESSION 3** **Human Centric Robotics** Chair: **Jianwei Zhang**, University of Hamburg, Germany

1445 – 1510	**Ensuring Safety of Humans and Industrial Robots Sharing the Same Workspace** **Masayoshi Tomizuka**, University of California, Berkeley, USA
1510 – 1535	**Cognitive Sensing for Robotic Dexterous Operations** **Fuchun Sun**, Tsinghua University, China
1535 – 1600	**Bipedal Walking: A Pluridisciplinary Perspective** **Jean-Paul Laumond**, LAAS-CNRS, France
1600 – 1625	*PM Break – L4 Pre-Function Area*
1625 – 1805	SESSION 4 **Advanced Robot Design** Chair: **Ronald Lumia**, University of New Mexico, USA
1625 – 1650	**Ten Technologies That Will Change Robotics, and the World, Forever** **Gregory Chirikjian**, Johns Hopkins University, USA
1650 – 1715	**Design of Robotic Systems to Trace Specified Curves** **Michael McCarthy**, University of California, Irvine, USA
1715 – 1740	**Design and Application of Parallel-Parallel 6-Legged Robots** **Feng Gao**, Shanghai Jiao Tong University, China
1740 – 1805	**Robotic Technology Efforts at the NASA/Johnson Space Center** **Myron Diftler**, NASA Johnson Space Center, USA

Special Session Speakers

Kok-Meng Lee, Georgia Institute of Technology, USA

Alternative Sensing and Perception based on Physical fields for Robotics and Automation
Recent advances in sensing and perception systems (SPSs), which move beyond from point measurements to field representation, enable exciting new technologies to facilitate autonomous machines capable of evolving with more and more 'smart functions' that ultimately make the process a self-improved system. This talk introduces several SPS methods based on physical fields as an alternative or a complement to visible light which is commonly assumed as the medium in conventional machine vision. As will be illustrated with practical robotics/automation examples, physical fields that exist both in man-made systems and in nature can be reconstructed from limited measurements to infer motion variables for guiding navigation and/or identify system properties of a distributed-parameter system to control its system behaviors; thus, their creative uses can eliminate costly, complicated external measurement systems. Selected applications of physical fields, which include electromagnetic and displacement fields in intelligent manufacturing applications and geomagnetic and thermal fields in nature, are given to help illustrate the impacts and yet to cover a wide variety of applications. The objective is to stimulate discussion of the future SPS research and its emerging applications to address problems facing society in a rapidly changing world.
Bio: Dr.Kok-Meng Lee received his S. M. and Ph. D. degrees in mechanical engineering from the Massachusetts Institute of Technology in 1982 and 1985 respectively. Since 1985, Dr. Lee has been a faculty with the George W. Woodruff School of Mechanical Engineering at

Georgia Institute of Technology. Currently, he is Professor of Mechanical Engineering at Georgia Tech and is Distinguished Professor with the State Key Laboratory of Digital Manufacturing Equipment and Technology at Huazhong University of Science and Technology under the National Recruitment Program of Global Experts. He was also honored as Pao Yu-Kong Chair Professor at Zhejiang University. His research interests include system dynamics/control, robotics, automation, machine vision, and mechatronics. Dr. Lee is a fellow of IEEE and ASME. Recognitions of his research contributions include the NSF Presidential Young Investigator (PYI) Award, Sigma Xi Junior Faculty Award, International Hall of Fame New Technology Award, Woodruff Faculty Fellow, three best paper awards and ten U. S., Canada and European patents. He is also recognized as advisor for nine Best Student Paper and Thesis Awards.

Dr. Lee is founding Editor-in-Chief for the Springer *International Journal on Intelligent Robotics and Applications*. Prior to this appointment, he served as Editor-in-Chief (2008-2013) and Technical Editor (1995-1999) for the *IEEE/ASME Transactions on Mechatronics*, Associate Editor for *IEEE Robotics and Automation Society Magazine* (1994-1996), *IEEE Transactions on Robotics and Automation* (1994-1998) and *IEEE Transactions on Automation Science and Engineering* (2003-2005). He was ICRA Local Chair (1993), IEEE/ASME AIM General Co-Chair (1997) and General Chair (1999) and as ASME Liaison for IEEE/ASME AIM (1999-2013, 2017-persent).

Nancy Amato, Texas A&M University, USA

Sampling-Based Motion Planning: Advances and Challenges

Motion planning has application in robotics, virtual prototyping and training, and even protein folding and drug design. Surprisingly, sampling-based planning methods have proven effective on problems from all these domains. In this talk we review some advances in sampling-based planning, including strategies that are well suited for manipulation planning and that can exploit workspace topology to improve planning time, and state some challenges.

Bio: Nancy M. Amato is Regents Professor and Unocal Professor of Computer Science and Engineering at Texas A&M University where she co-directs the Parasol Lab. Her main areas of research focus are robotics and motion planning, computational biology and geometry, and parallel and distributed computing. Amato received undergraduate degrees in Mathematical Sciences and Economics from Stanford University, and M.S. and Ph.D. degrees in Computer Science from UC Berkeley and the University of Illinois, respectively. She was program chair for the 2015 IEEE Intern. Conference on Robotics and Automation (ICRA) and for Robotics: Science and Systems (RSS) in 2016, is General Co-Chair for the 2017 International Symposium on Robotics Research (ISRR), and is the chair of the Steering Committee for the Workshop on the Algorithmic Foundations of Robotics. She as served as an elected member of the IEEE Robotics and Automation Society (RAS) AdCom (2009-2014) and is Chair of the IEEE RAS Electronic Products and Services Board (EPSB). She is an elected member of the CRA Board of Directors (2014-2017), is co-Chair of CRA-W (2014-2017), and was co-chair of the NCWIT Academic Alliance (2009-2011). She received the 2014 CRA Haberman Award, the inaugural NCWIT Harrold/Notkin Research and Graduate Mentoring Award in 2014, the 2013 IEEE HP/Harriet Rigas Award, and a Texas A&M AFS university-level teaching award in 2011. She received an NSF CAREER Award and is a AAAS Fellow, an ACM Fellow and an IEEE Fellow.

Han Ding, Huazhong University of Science & Technology, China

Robotic Machining: Challenges and Chances

Motivated by the technology of intelligent manufacturing, robots are springing up like mushrooms in a variety of machining applications, such as robotic milling, grinding, drilling and polishing etc. Although some fundamental problems, such as the mechanism of material-removing processes, how to design tools and plan tool paths, have been thoroughly investigated in the traditional manufacturing society, robotic processing still has to encounter unavoidable obstacles to achieve high performance machining. In order to maximize the potential of robotic processing, it is urgent to understand the theoretic and technique challenges and overcome them. This talk is intended to review the latest development of robotic processing, to discuss the challenges of robotic machining process from the interdisciplinary viewpoint, and to present the new development results achieved by our team. In particular, a successful application case, i.e., robotic grinding of blade parts, will be introduced. At the end, new trends and chances in this field will be outlined.

Bio: Prof. Han Ding received his Ph.D. degree in Mechatronics from Huazhong University of Science & Technology in 1989. Supported by the Alexander von Humboldt Foundation, Prof. Ding worked at University of Stuttgart, Germany in 1993. He obtained the National Distinguished Youth Scientific Fund in 1997 and was employed as the "Cheung Kong" Chair Professor at Shanghai Jiao Tong University in 2001. He was elected a member of Chinese Academy of Sciences in 2013.

Prof. Ding has long dedicated himself to the research work in the field of robotics and digital manufacturing and successfully combines the robotics and manufacturing technologies. He published three academic books and more than 300 journal papers, and licensed more than 60 patents in China. Prof. Ding acted as an Associate Editor (2003-2007) and an Editor (2011-) of IEEE Transactions on Automation Science and Engineering. He was a Technical Editor of IEEE/ASME Trans. on Mechatronics from 2010 to 2014. Currently, he is a Senior Editor of IEEE Robotics and Automation Letters. As a General Co-Chair, he hosted the IEEE International Conference on Robotics and Automation held in Shanghai, China in 2011.

Joel Burdick, California Institute of Technology, USA

Recovery of Function in Major Spinal Cord Injury Using Spinal Stimulation and Assistive Robotics

Approximately 5,000,000 worldwide suffer from a serious spinal cord injury (SCI). Not only do the injured lose the ability to stand and walk (and sometimes move their arms), they suffer from additional injury-induced complications including loss of bladder and bowel control, decreased cardiovascular and pulmonary health, inability to regulate body temperature, and loss of muscle strength and bone density. The totality of the injury and its secondary dysfunctions makes daily activities of living a challenge. Because the median age of SCI in the U.S. is 32 years, SCI individuals amass an additional $1.4-$4.2 million in healthcare costs over their lifetimes.

A team of researchers at Caltech, UCLA, and Univ. of Louisville have been developing new technologies and new therapies for *motor complete* SCI patients—those who have lost motor control below the level of their injury. The centerpiece of this approach is a multi-electrode array that is implanted over the lumbosacral spinal cord either in in the epidural space between the dura and the interior of the vertebral canal, or on the skin over this area. When this technology is coupled with locomotor training (which can be provided by assistive robotic devices), and drug therapy when possible, our preliminary human studies have shown that SCI patients receiving this therapy cannot only stand independently and make some voluntary movements (after being in a wheel chair for over 3 years), but more importantly, can expect to make significant gains in cardiovascular health, muscle tone, as well as improved autonomic function such as bladder, bowel, blood pressure, and temperature regulation. After first reviewing our clinical successes, current research on new machine

algorithms for automated tuning of the stimuli parameters, and the interface of this technology with robotic devices will be reviewed.

Bio: Joel Burdick received his undergraduate degrees in mechanical engineering and chemistry from Duke University and M.S. and Ph.D. degrees in mechanical engineering from Stanford University. He has been with the department of Mechanical Engineering at the California Institute of Technology since May 1988, where he has been the recipient of the NSF Presidential Young Investigator award, the Office of Naval Research Young Investigator award, and the Feynman fellowship. He has been a finalist for the best paper award for the IEEE International Conference on Robotics and Automation in 1993, 1999, 2000, 2005, and 2016. He was appointed an IEEE Robotics Society Distinguished Lecturer in 2003, and received the *Popular Mechanics Breakthrough* award in 2011. Prof. Burdick's current research interests include rehabilitation of spinal cord injuries, nonlinear control of mechanical systems, sensor based robot motion planning, and multi-fingered robotic hand manipulation.

Max Meng, The Chinese University of Hong Kong, China

Micro Medical Robotics: Painless and Scarless
Research on micro medical robotics is attracting more and more public attention and research efforts lately. Recent revolutionary development and drastic progress in robotic technology in terms of both hardware capability and software power have made it possible for researchers to redefine what micro medical robotics can achieve to facilitate complicated medical procedures with much less pain and surgical procedures without even external scars. In this talk, we will start with an introduction to how research on micro medical robotics started and what the milestone achievements are, and then move onto our own research efforts on micro medical robotics with several case study examples. Personal thoughts and outlook on future research efforts and potentials in micro medical robotics will be outlined to conclude the talk.

Bio: Max Q.-H. Meng received his Ph.D. degree in Electrical and Computer Engineering from the University of Victoria, Canada, in 1992, following his Master's degree from Beijing Institute of Technology in 1988. He joined the Chinese University of Hong Kong in 2001 and is currently serving as Professor and Chairman of Department of Electronic Engineering at the Chinese University of Hong Kong. He was a professor in the Department of Electrical and Computer Engineering at the University of Alberta in Canada, serving as the Director of the ART (Advanced Robotics and Teleoperation) Lab and holding the positions of Assistant Professor (1994), Associate Professor (1998), and Professor (2000), respectively. He was jointly appointed as an Overseas Outstanding Scholar Chair Professor of the Chinese Academy of Sciences and the Dean of the School of Control Science and Engineering at Shandong University in China. He is currently jointly appointed as a Distinguished Chair Professor at Harbin Institute of Technology supported via the 1000 Talents Recruitment Program of Global Experts, a Distinguished Provincial Chair Professor of Henan University of Science and Technology, and the Honorary Dean of the School of Control Science and Engineering at Shandong University, in China. His research interests include robotics, perception and sensing, human-robot interaction, active medical devices, bio-sensors and sensor networks, and adaptive and intelligent systems. He has published more than 500 journal and conference papers and book chapters and led more than 40 funded research projects to completion as Principal Investigator. He has served as an editor of the IEEE/ASME Transactions on Mechatronics and an associate editor of the IEEE Transactions on Fuzzy Systems, and is currently a technical editor of a number of journals in robotics. He has served as the General Chair of several conferences, including IROS 2005, AIM 2008, WCICA 2010, and Robio 2013 conferences. He is the founder of the IEEE ICIA conference series and co-founder of the IEEE Robio conference series. He served as an Associate VP for Conferences of the IEEE Robotics and Automation Society (2004-2007),

an AdCom member of the IEEE Neural Network Council/Society (2003-2006), the Co-Chair of the Fellow Evaluation Committee of the IEEE Robotics and Automation Society. He is currently serving as an elected member of the Administrative Committee (AdCom) of the IEEE Robotics and Automation Society. He is a recipient of the IEEE Third Millennium Medal award and he is a Fellow of IEEE.

Bradley Nelson, EidgenössischeTechnische Hochschule (ETH) Zürich, Switzerland

Opportunities at the Bottom
While the futuristic vision of micro and nanorobotics is of intelligent machines that navigate throughout our bodies searching for and destroying disease, we have a long way to go to get there. Progress is being made, though, and the past decade has seen impressive advances in the development of tiny motile devices. In this talk I will discuss what our research community has accomplished in the areas of propulsion and actuation, sensing, *in vivo* delivery, precision surgery, and detoxification. I will also discuss emerging areas and their potential impact. As systems such as these progress and enter clinical trials, and as commercial applications of this new technology are realized, radically new therapies and uses will result that have yet to be envisioned.
Bio: Brad Nelson has been the Professor of Robotics and Intelligent Systems at ETH Zürich since 2002. He has over thirty years of experience in the field of robotics and has received a number of awards in the fields of robotics, nanotechnology, and biomedicine. He serves on the advisory boards of a number of academic departments and research institutes across North America, Europe, and Asia and is on the editorial boards of several academic journals. Prof. Nelson has been the Department Head of Mechanical and Process Engineering at ETH, Chairman of the ETH Electron Microscopy Center, is a member of the Research Council of the Swiss National Science Foundation, and serves on boards of three Swiss companies. Before moving to Europe, Prof. Nelson worked as an engineer at Honeywell and Motorola and served as a United States Peace Corps Volunteer in Botswana, Africa. He has also been a professor at the University of Minnesota and the University of Illinois at Chicago.

Masayoshi Tomizuka, University of California, Berkeley, USA

Ensuring Safety of Humans and Industrial Robots Sharing the Same Workspace
Robots play significant roles in modern factory automation. While researchers strive to make robots more intelligent and autonomous, there are also significant developments in recent years to allow humans and robots to work together to make the manufacturing process more efficient, effective, flexible and intelligent. There are advantages and disadvantages to humans and robots, and co-robot ideas have been pursued by universities, research laboratories and robot manufacturers. We will address the fundamental issue of safety and propose a theoretical framework to ensure safety when robots and humans share the same work space on the factory floor.
Bio: Masayoshi Tomizuka received his B.S. and M.S. degrees in Mechanical Engineering from Keio University, Tokyo, Japan and his Ph. D. degree in Mechanical Engineering from the Massachusetts Institute of Technology in February 1974. In 1974, he joined the faculty of the Department of Mechanical Engineering at the University of California at Berkeley, where he currently holds the Cheryl and John Neerhout, Jr., Distinguished Professorship Chair. His research interests are optimal and adaptive control, digital control, motion control, and control problems related to robotics and rehabilitation, vehicles and mechatronic systems. He served as Program Director of the Dynamic Systems and Control Program of the National Science

Foundation (2002-2004). He has supervised more than 110 PhD students to completion. He served as President of the American Automatic Control Council (AACC) (1998-99), and he chaired the IFAC (International Federation of Automatic Control) Technical Committee on Mechatronic Systems. He is a Fellow of the ASME, the Institute of Electric and Electronics Engineers (IEEE), IFAC and the Society of Manufacturing Engineers. He is the recipient of the J-DSMC Best Paper Award (1995, 2010), the DSCD Outstanding Investigator Award (1996), the Charles Russ Richards Memorial Award (ASME, 1997), the Rufus Oldenburger Medal (ASME, 2002) and the John R. Ragazzini Award (AACC, 2006).

Fuchun Sun, Tsinghua University, China

Cognitive Sensing for Robotic Dexterous Operations
Next-generation intelligent robots will be required to be appropriately equipped with multi-modal information perception and fusion modules for better dexterous operation capability, and hopefully, they will be broken through from the aspects of perception, representation/fusion of cross-modal sensing information and action behavior like human being. In this talk, we will present the developed high-resolution four-modal sensor device which contains micro-vision, tactile/slip sensors and temperature. We also develop a new type of dexterous hand which is equipped with such four-modal device for muscle-like actuation. Some advanced cross-modal information processing approaches such as deep learning and reinforcement learning are proposed to solve the joint representation of visual-tactile fusion and sensing- actuation mapping problems. Finally, we show some experimental demos using the multi-modal experience learning and present some future directions.
Bio: Dr.Fuchun Sun is professor of Department of Computer Science and Technology and President of Academic Committee of the Department, Tsinghua University, deputy director of State Key Lab. of Intelligent Technology & Systems, Beijing, China. His research interests include robotic perception and intelligent control. He has won the <u>Champion</u> of Autonoumous Grasp Challenges in IROS2016.
Dr. Sun is the recipient of the excellent Doctoral Dissertation Prize of China in 2000 by MOE of China and the Choon-Gang Academic Award by Korea in 2003, and was recognized as a Distinguished Young Scholar in 2006 by the Natural Science Foundation of China. He served as an associated editor of IEEE Trans. on Neural Networks during 2006-2010, IEEE Trans. on Fuzzy Systems since 2011 and IEEE Trans. on Systems, Man and Cybernetics: Systems since 2015.

Jean-Paul Laumond, LAAS-CNRS, France

Bipedal Walking: A Pluridisciplinary Perspective
The talk reports on a research action exploring the motor synergies of anthropomorphic walking. By combining biomechanical, neurophysiology, and robotics perspectives, it is intended to better understand human locomotion with the ambition to better design bipedal robot architectures. The motivation of the research starts from the simple observation that humans may stumble when following a simple reflex-based locomotion on uneven terrains. The rationale combines two well established results in robotics and neuroscience, respectively: first, passive robot walkers, which are very efficient in terms of energy consumption, can be modeled by a simple rotating rimless wheel; second, humans and animals stabilize their head when moving. The seminal hypothesis is then to consider a wheel equipped with a stabilized mass on top of it as a plausible model of bipedal walking, the so-called Yoyo-Man. We will see recent results supporting this hypothesis. These results open

new perspectives to explore the computational foundations of anthropomorphic walking and to design new humanoid robots.

Bio: Jean-Paul Laumond, IEEE Fellow, is a roboticist. He is Directeur de Recherche at LAAS-CNRS in Toulouse, France. He received the M.S. degree in Mathematics, the Ph.D. in Robotics and the Habilitation from the University Paul Sabatier at Toulouse in 1976, 1984 and 1989 respectively. From 1976 to 1983 he was teacher in Mathematics. He joined CNRS in 1985. In Fall 1990 he has been invited senior scientist from Stanford University. His research is devoted to robot motion. In 2000 created and managed Kineo CAM, a spin-off company from LAAS-CNRS devoted to develop and market motion planning technology. The company was awarded the third IEEE-IFR prize for Innovation and Entrepreneurship in Robotics and Automation in 2005. Siemens acquired Kineo CAM in 2012. In 2006, Laumond launched the research team Gepetto dedicated to Human Motion studies along three perspectives: artificial motion for humanoid robots, virtual motion for digital actors and mannequins, and natural motions of human beings. His current project Actanthrope is supported by the European Research Council (ERC) and devoted to the computational foundations of anthropomorphic action. He teaches Robotics at Ecole NormaleSupérieure in Paris. He has published more than 150 papers in international journals and conferences in Robotics, Computer Science, Automatic Control and Neurosciences. He has been the 2011-2012 recipient of the Chaire Innovation technologique Liliane Bettencourt at Collège de France in Paris. He is a member of the French Academy of Technologies. He is the 2016 recipient of the IEEE Inaba Technical Award for Innovation Leading to Production.

Gregory Chirikjian, Johns Hopkins University, USA

Ten Technologies That Will Change Robotics, and the World, Forever
Breakthroughs in hardware miniaturization driven by the large markets for computers, cameras, and phones are impacting the field of robotics in very positive ways. Moreover, algorithms for handling the resulting `big data' are making impressive progress. This talk will make some predictions about how the field of robotics will harness these and other emerging technologies, and explore some of the resulting impacts on human society.

Bio: Gregory S. Chirikjian received undergraduate degrees from Johns Hopkins University in 1988, and the Ph.D. degree from the California Institute of Technology, Pasadena, in 1992. Since 1992, he has been on the faculty of the Department of Mechanical Engineering, Johns Hopkins University, where he has been a full professor since 2001. From 2004-2007 he served as department chair. In 2014-15 he served as one of the program directors for the US National Robotics Initiative and continued to serve the National Science Foundation as an `expert' in 2016. His research interests include snakelike, continuum, and modular reconfigurable robots, applications of group theory in a variety of engineering disciplines, and the mechanics of biological macromolecules. He is a 1993 National Science Foundation Young Investigator, a 1994 Presidential Faculty Fellow, and a 1996 recipient of the ASME Pi Tau Sigma Gold Medal. In 2008 he became a Fellow of the ASME, and in 2010 he became a Fellow of the IEEE. He is the author of more than 250 journal and conference papers and primary author on three books: Engineering Applications of Noncommutative Harmonic Analysis (2001) and Stochastic Models, Information Theory, and Lie Groups, Vols. 1+2. (2009,2011). In 2016 and expanded edition of his 2001 book came out as a Dover book under the new title: Harmonic Analysis for Engineers and Applied Scientists.

Michael McCarthy, University of California, Irvine, USA

Design of Robotic Systems to Trace Specified Curves

This talks examines design techniques for mechanical systems that trace specified curves such as the foot movement for walking robots or the wing tip trajectory for flying robots. We consider the design of four-bar and six-bar linkages that control serial chains to trace these curves. Then we show that mechanical Fourier synthesis can be used to draw a wide range of curves. And finally, we present a system of mechanically coupled serial chains that can be configured to sign your name with a single actuator.

Bio: J. Michael McCarthy is the Director of UCI's Performance Engineering Program, having completed a eight year term as the Henry Samueli Professor and Director of the Center for Engineering Science in Design at the University of California, Irvine, which supports the design and execution of team engineering projects across the School of Engineering.

He received his Ph.D. at Stanford University, and has taught at Loyola Marymount University and the University of Pennsylvania before joining UCI in 1986. He has over 200 publications and five books including The Geometric Design of Linkages (Springer 2000, 2nd Ed. 2010). He has served as the Editor-in-Chief of the ASME Journal of Mechanical Design (2002-2007) and is the founding Editor-in-Chief of the ASME Journal of Mechanisms and Robotics (2007-2014).

His research team is responsible for the Sphinx, Synthetica and MecGen software packages, which extend computer-aided design to spherical and spatial linkage systems and integrate this process with geometric modeling. He has organized and presented tutorials on the design of linkages and robotic systems at ASME and IEEE conferences, including the NSF sponsored 2012 Workshop on 21st Century Kinematics.

He is a Fellow of the American Society of Mechanical Engineers (ASME), and has received the 2009 ASME Machine Design Award, the 2011 ASME Mechanisms and Robotics Award, and the 2013 Robert E. Abbott Lifetime Service Award from the Design Engineering Division of ASME International. At the 2015 Mechanisms and Robotics Conference, he and his co-author received the A.T. Yang Memorial Award in Theoretical Kinematics for their paper on the design of a linkage system that reproduces the flapping motion of a bird in flight.

Feng Gao, Shanghai Jiao Tong University, China

Design and Application of Parallel-Parallel 6-Legged Robots

Research on walking robots has been one of key topics in robotics for a long time. In recent years, many legged robots were developed in the world, which of them achieved great progress and received much attention from the robotic field. For the control of legged robots, one of the most important challenging issues is the human robot Interaction for the real time control of the legged robots. This talk will introduce our research on both mechanism design and real time control for the parallel-parallel 6-legged robots related to the human robot Interaction, which include the following issues: design process of type synthesis for legged robots by G_F set theory, real-time operating system for legged robots, hexapod robot with 500kg payload, hexapod robot with safe riding capability, walking based on force sensing without force sensors, obstacle avoidance with both vision and F/T sensor, walking upstairs by vision & downstairs by terrain memory, human-robot interactive assembly based on F/T sensor, manufacturing based on F/T sensor, locked door opening based on F/T sensor for legged robots, and so on.

Bio: Feng Gao was born on Dec. 21, 1956 in Jiujiang City of Jiangxi Provence, P. R. of China. He got his Ph.D. in mechanical engineering from the Beijing University of Aeronautics and Astronautics in 1991 and his Master in mechanical engineering from the Northeast Heavy Machinery Institute, China in 1982. From 1976 to 1979, he was a student in mechanical engineering at the Northeast Heavy Machinery Institute, China. From 1995 to 1997, he was a postdoctoral research associate in the School of Engineering Science at Simon Fraser University, Canada.

He has been serving as an Associate Editor of Mechanism and Machine Theory and the ASME Journal of Mechanisms and Robotics since 2008 and the ASME Journal of Mechanical Design since 2012, and the General Member of the ASME Mechanisms and Robotics Committee since 2012. He gave the Keynote Speeches on the conferences of the ASME 2012 and IFToMM 2015, respectively. He won the 2013 China National Natural Science Award because of his contributions in parallel mechanism design and the 8 items of awards from the provincial science and technology invention prizes in China. 2014. Dr. Gao won 2014 ASME Leonardo Da Vinci Award for his invention of parallel manipulators.

His chief research domain is the parallel robots. The major achievements obtained include the design theory, invention and application of the parallel robots. In the theory aspect, he proposed the G_F Set Theory for the type synthesis of parallel robotic mechanisms, the evaluating performance criteria and the physical model of the solution space for dimensional designing of parallel robotic mechanisms. In the application aspect, he Invented and Designed many kinds of the robots and machines with parallel mechanisms for heavy load applications He published 3 books and 288 papers. The 96 invention patents of China were authorized.

Myron Diftler, NASA Johnson Space Center, USA

Robotic Technology Efforts at the NASA/Johnson Space Center

The NASA/Johnson Space Center has been developing robotic systems in support of space exploration for more than two decades. The goal of the Center's Robotic Systems Technology Branch is to design and build hardware and software to assist astronauts in performing their mission. These systems include: rovers, humanoid robots, inspection devices and wearable robotics. Inspection systems provide external views of space vehicles to search for surface damage and also maneuver inside restricted areas to verify proper connections. New concepts in human and robotic rovers offer solutions for navigating difficult terrain expected in future planetary missions. An important objective for humanoid robots is to relieve the crew of "dull, dirty or dangerous" tasks, allowing them more time to perform their important science and exploration missions. Wearable robotics one of the Center's newest development areas can provide crew with low mass exercise capability and also augment an astronaut's strength while wearing a space suit.

This talk will describe the robotic technology and prototypes developed at the Johnson Space Center that are the basis for future flight systems. An overview of inspection robots will show their operation on the ground and in-orbit. Rovers with independent wheel modules, crab steering, and active suspension are able to climb over large obstacles, and nimbly maneuver around others. Humanoid robots, including the First Humanoid Robot in Space: Robonaut 2, demonstrate capabilities that will lead to robotic caretakers for human habitats in space, and on Mars. The Center's Wearable Robotics Lab supports work in assistive and sensing devices, including exoskeletons, force measuring shoes, and grasp assist gloves.

Bio: Dr.Diftler currently serves as the Chief of the Robotic Systems Technology Branch at the NASA Johnson Space Center (JSC). He is responsible for projects in the areas of: Humanoid Robotics, Wearable Robotics, and Mobility Systems. Dr.Diftler led the development of the Robonaut 2 (R2) humanoid robot project in collaboration with General Motors which resulted in an R2 unit undergoing testing on the International Space Station. In addition to collaboration with GM, Dr.Diftler led his team through previous collaborations with the Defense Advanced Research Projects Agency (DARPA), Johns Hopkins University, Vanderbilt University, the Massachusetts Institute of Technology, the University of Massachusetts, the University of Southern California, Rice University, and the Institute for Human-Machine Cognition.

Dr.Diftler holds a B.S.E. in Mechanical and Aerospace Engineering from Princeton University, a M.S. in Electrical Engineering from Yale University and a Ph.D. Mechanical Engineering from Rice University. His research interests include humanoid robotics,

dexterous manipulation, impedance control and human augmentation. Dr.Diftler has published more than 50 peer reviewed technical papers in robotic systems and helicopter dynamics. He has 11 patents currently in process or awarded in the field of robotics including several on robot hand technology. Dr.Diftler is a recipient of a 2012 Service to America Finalist Medal, a 2009 NASA Exceptional Engineering Achievement Award, a 2005 IEEE Humanoids Conference Best Paper Award, and a 2004 NASA Public Service Medal.

Robotics Innovation and Entrepreneurship Forum

ICRA 2017 will introduce a new Robotics Innovation & Entrepreneurship (RIE) Forum that aims to bridge technological advances with real-world problems. The forum will connect promising start-ups with industry leaders in six key application domains: **autonomous driving**, **logistics**, **healthcare**, **service**, **collaborative manufacturing** and **education and social**.

Format

Industry leading companies will showcase their latest developments and real-world needs. After each topical industry presentation, up to four start-ups will be given the opportunity for a 5-minute pitch of their solution(s) to the main conference audience. A panel representing the industry, investor community, entrepreneurial experts and capability leaders, will select the winning pitch for each focus area.

Call to Start-ups for Participation

Start-up companies in any of the above-mentioned RIE Forum focus areas are invited to submit their application for the pitch session on the ICRA 2017 website. One speaker from each shortlisted start-up will be given a complimentary (exhibitor) pass; other team members can purchase an exhibitor pass at SGD 450. All shortlisted start-up companies will be invited to participate in the Start-up Corner in the main conference hall, where space will be provided for the company to present their product offering.

Tuesday - May 30, 2017

Venue: Sands O (Level 5, next to Grand Ballroom)

TIME	SESSIONS	INVESTORS
0955 – 1115	**SESSION 1** **Autonomous Driving** Chair: **Jim Ostrowski**, Blue River Technology, USA	
0955 – 1010	**Singapore's Vision for Autonomous Vehicle Deployment** **Chris Leck**, Director of Futures Division, Ministry of Transport, Singapore	- Armstrong Industrial Corporation - Clear Water Bay Startup Fund
1010 – 1025	**Cloud Robotics: Intelligent Machines in a Cloud-Connected World** **James Kuffner**, CTO, Toyota Research Institute, USA	
1025 – 1040	**nuTonomy: Driving towards tomorrow** **Emilio Frazzoli**, CTO, nuTonomy, Singapore	

1040 – 1055	Start-ups	
1055 – 1115	Q&A with Panel Discussion	
1115 – 1135	*AM Break – L5 Grand Ballroom Foyer*	
1130 – 1245	**SESSION 2** **Logistics Robotics** Chair: **Michael Lau**, Newcastle University International, Singapore	
1130 – 1145	**Emergence of Intelligent Logistics Picking Systems** **Rosen Diankov**, CTO, Mujin, Japan	- BP Digital Innovation Organization - Clear Water Bay Startup Fund
1145 – 1200	**Robotics in Logistics: DPDHL Trend Study and Pilots** **Tamanna Dahiya**, Director of APAC Innovation Center, DHL Customers Solution & Innovation, Singapore	
1200 – 1220	Start-ups	
1220 – 1245	Q&A with Panel Discussion	
1245 – 1345	*Lunch Break – L5 Grand Ballroom Foyer*	
1445 – 1600	**SESSION 3** **Service Robotics** Chair: **Jim Ostrowski**, Blue River Technology, USA	
1445 – 1500	**The Business of Delivering Delivery Robots** **Steve Cousins**, CEO, Savioke, USA	- Clear Water Bay Startup Fund
1500 – 1515	**Scaling Research to Consumer Products** **Stefan Grufman**, Teamleader Software & Signal team, Husqvarna Group, Sweden	
1515 – 1535	Start-ups	
1535 – 1600	Q&A with Panel Discussion	

1600 – 1625	*PM Break – L5 Grand Ballroom Foyer*	
1625 – 1740	**SESSION 4** **Healthcare Robotics** Chair: **Bert Grobben**, Founder & CEO, Budding Innovations, Singapore	- Armstrong Industrial Corporation - Clear Water Bay Startup Fund
1625 – 1640	**CHARTing Future Healthcare Delivery** **Selina Seah**, ACEO, Changi General Hospital, Singapore	
1640 – 1655	**da Vinci Robotic Surgery Platform – A product development perspective** **Pushkar Hingwe**, Director of Robotic Motion Control, Intuitive Surgical, USA	
1655 – 1715	Start-ups	
1715 – 1740	Q&A with Panel Discussion	

Wednesday - May 31, 2017

Venue: Sands O (Level 5, next to Grand Ballroom)

TIME	SESSIONS	INVESTORS
0930 – 1045	**SESSION 5** **Collaborative Manufacturing** Chair: **Michael Lau**, Newcastle University International, Singapore	- Clear Water Bay Startup Fund - GreenMeadows Accelerator
0930 – 0945	**Yasuhiko Hashimoto**, General Manager, Robot Division, Kawasaki Heavy Industry, Japan	
0945 – 1000	**Keeping Pace with Technology Advancement and Disruption through Industry-led Public-private Partnership in Advanced Manufacturing R&D** **David Low**, CEO, Advanced Remanufacturing Technology Centre (ARTC), Singapore	
1000 – 1020	Start-ups	
1020 –	Q&A with Panel Discussion	

1045		
1045 – 1105	*AM Break – L5 Grand Ballroom Foyer*	
1105 – 1220	**SESSION 6** **Education and Social Robotics** Chair: **Bert Grobben**, Founder & CEO, Budding Innovations, Singapore	- Clear Water Bay Startup Fund
1105 – 1120	**Robots for Early Childhood Education** **Adrian Lim**, Director of Education Sector, Sectoral Innovation Group, Info-communications Media Development Authority (IDMA), Singapore	
1120 – 1135	**Bring Alive Our Dream Robot with the Developer Community** **Sarah Zhang**, Head of Developer Partnerships & Business Operations, Segway Robotics Inc., China	
1135 – 1155	Start-ups	
1155 – 1220	Q&A with Panel Discussion	

RIE Forum Speakers

0955 – 1010, Tuesday – May 30, 2017, Sands O (Level 5)

Singapore's Vision for Autonomous Vehicle Deployment

Chris Leck

Director of Futures Division, Ministry of Transport, Singapore

The presentation will give an overview of Singapore's vision for the deployment of Autonomous Vehicles as well as of on-going Autonomous Vehicle trials in Singapore.

Bio: Chris Leck recently took up the appointment of Director, Futures Division, at the Singapore Ministry of Transport, where he also oversees the Emergency Planning unit. Prior to this, he served as Head of Strategic and Political-Military Planning at the Singapore Ministry of Defence. Chris graduated with a bachelor's degree in Government & Economics in 1999, and also completed master's degrees in international relations and international law.

1010 – 1025, Tuesday – May 30, 2017, Sands O (Level 5)

Cloud Robotics: Intelligent Machines in a Cloud-Connected World

James Kuffner

CTO, Toyota Research Institute, USA

The Automotive and Robotics industries are currently undergoing dramatic transformations. High-performance networking and cloud computing has radically altered how individuals and businesses manage data and computation. A new generation of cloud-enabled robots, a.k.a. "Cloud Robotics", is now poised to fundamentally disrupt the state-of-the-art in the development of intelligent machines. The long-term prospects for the future evolution of robot intelligence based on search, distributed computing, machine learning, and big data will enable future robotic systems to be more capable and useful.

Bio: Dr. James Kuffner is the Chief Technology Officer at the Toyota Research Institute (TRI) and serves as Area Lead, Cloud Intelligence. Dr. Kuffner received a Ph.D. from the Stanford University Dept. of Computer Science Robotics Laboratory in 1999, and was a Japan Society for the Promotion of Science (JSPS) Postdoctoral Research Fellow at the University of Tokyo working on software and planning algorithms for humanoid robots. He joined the faculty at Carnegie Mellon University's Robotics Institute in 2002.
Dr. Kuffner is perhaps best known as co-inventor of the Rapidly-exploring Random Tree (RRT) algorithm, which has become a key standard benchmark for robot motion planning. He has published over 125 technical papers, holds more than 40 patents, and received the Okawa Foundation Award for Young Researchers in 2007.
Before joining TRI, Dr. Kuffner was a Research Scientist and Engineering Director at Google from 2009 to 2016. Dr. Kuffner was part of the initial engineering team that built Google's self-driving car. In 2010, he introduced the term "Cloud Robotics" to describe how network-

connected robots could take advantage of distributed computation and data stored in the cloud. Dr. Kuffner was appointed head of Google's Robotics division in 2014, which he co-founded along with Andy Rubin.

Dr. Kuffner continues to serve as an Adjunct Associate Professor at the Robotics Institute, Carnegie Mellon University.

1025 – 1040, Tuesday – May 30, 2017, Sands O (Level 5)

nuTonomy: Driving towards tomorrow

Emilio Frazzoli

CTO, nuTonomy, Singapore

How is technology going to change mobility in the future? How will our lives and our cities change as autonomous cars become a reality? In this talk I will explain the vision that is being pursued by nuTonomy, for a future in which safe, reliable, and affordable mobility is provided to all through a fleet of autonomous shared vehicles, augmenting and complementing other transportation options.

1130 – 1145, Tuesday – May 30, 2017, Sands O (Level 5)

Emergence of Intelligent Logistics Picking Systems

Rosen Diankov

CTO, Mujin, Japan

In the past year, the Mujin PickWorker product has succeeded in commercializing logistics picking tasks like random depalletization, order fulfillment, item packing, random palletization, random box picking, and conveyor tracking. All of these tasks involve tight sensor integration and years of planning and testing edge cases to overcome all the computer vision and robot control challenges necessary to achieve reliable, non-stop intelligent picking; in contrast, the Mujin PickWorker can be configured from scratch and become deployment ready within days.

Advanced robotics research is full of computer vision algorithms, motion planning algorithms, multi-dof motor control methods, gripper designs, parallelization techniques, and overall architecture design ideas; unfortunately getting the right combination of these technologies to deliver a solid picking system for logistics is extremely hard. Many companies worldwide are rushing to commercialize intelligent picking systems in the logistics sector, but the jury is still out on which methods are the best and what such systems will look like when deployed.

The Mujin PickWorker system leverages the latest advances in robotics algorithms while condensing an incredible amount of computation in a tight real-time loop to achieve fast picking cycles comparable to humans. In this talk, I will present the Mujin product line-up, system architecture, development methodologies, and how our team is pushing the state of art in intelligent logistics picking systems.

Robotics in Logistics: DPDHL Trend Study and Pilots

Tamanna Dahiya

Director of APAC Innovation Center, DHL Customers Solution & Innovation, Singapore

The presentation will focus on near term and longer term use cases of robotics in logistics operations as summarized in DHL Trend study and the learnings from the pilots being conducted in this area.

Bio: Tamanna Dahiya leads customer engagements and trends research projects for DHL Asia Pacific Innovation Center (APIC). APIC is part of a DHL global innovation platform with a mission to inspire, connect and engage industries on the future of logistics. With experience in consulting and supply chain industries for the last 10 years, Tamanna now focuses on working with DHL business units, customers and external partners to fuel innovative ideas and bring innovative solutions to life. She has a keen interest in all areas of innovation in logistics.

The Business of Delivering Delivery Robots

Steve Cousins

CEO, Savioke, USA

Bio: Steve Cousins is founder and CEO of Savioke, the leader in developing and deploying autonomous robots that work in human environments to improve people's lives. Before founding Savioke, Steve was President and CEO of robotics incubator Willow Garage, where he oversaw the creation of the robot operating system (ROS), an open source software suite that has become the standard tool among robotics researchers. Also at Willow Garage, Steve launched the industry's first personal robots including the PR2 and the TurtleBot. Prior to that, Steve was a member of executive teams at IBM's Almaden Research Center and Xerox PARC. He's active in the Robots for Humanity project and holds a PhD from Stanford University, BS and MS degrees in computer science from Washington University, and earned a micro-MBA while at IBM.

Scaling Research to Consumer Products

Stefan Grufman

Teamleader Software & Signal team, Husqvarna Group, Sweden

The talk from Husqvarna will be about how we, you the researchers and we the company, can bridge the gap between research and industrialization. It is the task for companies such as Husqvarna to implement and utilize research results in products, but in some cases the gap is very large. As an example, when and how can machine learning be used in commercial products with requirements on safety? What have we done (result/ideas) and what can we do to bridge this gap in the future?

Bio: Stefan Grufman has been developing embedded systems for more than 20 years. After graduating from LiU (Linköping Univeristy in Sweden) it has involved everything from consumer products to military aircrafts. A special interest during these years has been software architecture and especially model based software engineering. Since 2011, when Stefan joined Husqvarna Group, he has been working with research and pre-development for robotic lawnmowers. This work has been focused on researching the future technology and functionality of Husqvarna's robotics products. Today Stefan is leading the software and signal analysis team of the electric products research group at Husqvarna. Stefan will discuss and talk about the challenges related to scaling bleeding edge research into mass produced consumer products.

CHARTing Future Healthcare Delivery

Selina Seah

ACEO, Changi General Hospital, Singapore

Globally, developed countries are facing changing demographics where their populations are rapidly ageing. The future of healthcare requires new initiatives to transform care whilst ensuring that productivity of workforce is upheld. This presentation discusses opportunities for adopting solutions such as robotics and automation from perspective of augmenting healthcare service providers' daily operations and ensuring delivery of high standard of care for the general population.

Bio: Appointed as Assistant Chief Executive Officer CGH on 1 Sep 2012 focusing on campus development and care transformation, Ms Seah has leadership over remodelling of the campus, looking at new models of care and developing enablers in infrastructure, technology and innovations. She is also Director of the Centre for Healthcare Assistive & Robotics Technology (CHART), a partner of the National Robotics Program, to build a collaborative platform that will enable healthcare professionals to work closely with academia, industry and research institutions to develop impactful healthcare solutions leveraging on robotics and assistive technology.

Da Vinci Robotic Surgery Platform – A product development perspective

Pushkar Hingwe

Director of Robotic Motion Control, Intuitive Surgical, USA

Robot assisted surgery is bringing the advantages of minimally invasive surgery to procedures that were previously done open. The technology pillars: 3d Vision, intuitiveness and dexterity work together to make an effective robotic surgery platform. Da Vinci Xi system has further enhanced the capability of robotic surgery. Some engineering challenges that needed to be overcome during Xi development will be presented as examples of the effort needed to offer compelling patient and surgeon value.

Bio: Dr. Hingwe has been part of the algorithms group at Intuitive Surgical since 2008 and has been intimately involved with developing algorithms that control the robot behaviour and translate surgeons hand motion into surgical instrument motion. He is currently the Director of Systems Analysis in the New Product Development organization. He also leads the product development of the surgeon console. Prior to Intuitive he was in IBM-Hitachi in the disk drive business where he lead the motion control group. He graduated with a PhD from UC Berkeley in 1997 and was a post doc at UC Berkeley until 2000.

Yasuhiko Hashimoto

General Manager, Robot Division, Kawasaki Heavy Industry, Japan

Bio: Mr. Hashimoto graduated from the Faculty of Engineering, University of Tokyo. He joined KHI as a robotics engineer in 1981 and was involved in the design and development of various types of robots. In 1997, he spearheaded the launch of a new robotics business for the semiconductor industry. He established a new sales and marketing office of Kawasaki Robotics (USA), Inc. (KHI) in San Jose California, for semiconductor robots, and moving there to further develop and grow the business in 2001. He was promoted to Vice President of KRI in 2003 with responsibilities that included leading the semiconductor robotics business worldwide. Mr. Hashimoto returned to KHI Japan in 2009 and was appointed Deputy Manager of the Robot Division (Associate Officer). He was subsequently promoted to General Manager of Robot Division in 2012 and Executive Officer in 2013. Also in 2013, he established the joint venture company Medicaroid Corporation with Sysmex Corporation to expand KHI's product offering to the medical robotics field, and he has been holding the additional role of President of Medicaroid since. Mr. Hashimoto was appointed Managing Executive Officer of KHI in 2016 and carries on his role as the head of the Robot Division along with his new corporate responsibilities.

Keeping Pace with Technology Advancement and Disruption through Industry-led Public-private Partnership in Advanced Manufacturing R&D

David Low

CEO, Advanced Remanufacturing Technology Centre (ARTC), Singapore

Bio: Dr David Low is the CEO of the Advanced Remanufacturing and Technology Centre (ARTC) of the Agency for Science, Technology and Research (A*STAR) in Singapore. The ARTC is a public-private partnership led by A*STAR in partnership with the Nanyang Technological University (NTU). Currently the ARTC works with 44 industry members to develop advanced remanufacturing and manufacturing capabilities. The industry members include 3M, ABB, Barnes Aerospace, EOS, IHI, Rolls-Royce, National Instruments, Siemens, SKF, Trumpf and Zeiss and many more. David was previously the Chief of Manufacturing Technology - Singapore and Head of Process Technology Research Centre at Rolls-Royce. Prior to joining Rolls-Royce in 2007, David researched in the field of laser materials processing since 1998, during which he conducted industrial research for many companies and published over 50 journal, conference, patent and book publications. David received his PhD and Bachelor degree (1st class) in Mechanical Engineering from the University of Manchester. He received his Executive MBA from INSEAD and Tsinghua University.

1105 – 1120, Wednesday – May 31, 2017, Sands O (Level 5)

Robots for Early Childhood Education

Adrian Lim,

Director of Education Sector, Sectoral Innovation Group, Info-communications Media Development Authority (IDMA), Singapore

Robots for Early Childhood Education was initiated by the Infocomm Media Development Authority of Singapore to trial the use of social robots in complementing teaching and learning at the preschool. Robots in our daily life are becoming more prevalent, ranging from autonomous vehicles, industry robots and now social robots at home and in schools. Exposing age-appropriate technologies to the young and prepare them early is key for Singapore's push to be the world's first Smart Nation.

Two social robots were trialled at two preschools to study the practical aspects of using social robots for lessons. Observations on the experience and impact were studied during the trial through lesson designs around the area of collaborative play and interactive storytelling. The outcome of the trial shows children at the age 5-6 are very receptive to social robots in the classroom and this paves the way for future innovative lesson designs involving robots.

Bring Alive Our Dream Robot with the Developer Community

Sarah Zhang

Head of Developer Partnerships & Business Operations, Segway Robotics Inc., China

The presentation will focus on (1) how and why we built Loomo, a robotic platform that is extendable both in terms of hardware and software; (2) how start-ups can bring alive their own dream robots by simply building apps on Loomo and achieve social impact/commercial success.

- Loomo and our vision for Droid
- Extendibility is the key: hardware and software designs
- Win together through the developer program
- Apps built by BMW, MIT and more

Industry Forum

The Industry Forum has two key tracks: **Technology Innovations in Robots and Automations** and the **IERA Awards**. It runs parallel to the new Robotics Innovation & Entrepreneurship (RIE) Forum in the adjacent room.

The **Technology Innovations in Robots and Automations** sessions bring together well known and dynamic robotics and automation companies to share their experiences and advances in technological solutions to real world problems. The speakers are prominent and key position holders of their respective organizations. There is a mix of international and local companies in the four different sessions.

The two **IERA Award** sessions will highlight and honor the achievements of inventors and whose ideas translate into world-class products. The award is jointly sponsored by the IEEE Robotics and Automation Society (IEEE/RAS) and the International Federation of Robotics (IFR).

Tuesday - May 30, 2017

Venue: Sands N (Level 5, next to Grand Ballroom)

TIME	SESSIONS
0955 – 1110	**SESSION 1** **New Paradigms in Construction Automation and Robotics** Chair: **Erdal Kayacan**, Nanyang Technological University, Singapore *Co-organised with JTC*
0955 – 1010	**Overcoming Building & Infrastructure challenges with Robotics and Automation Solutions** **Soon Poh Heah**, Assistant CEO, JTC, Singapore
1010 – 1025	**Infrastructure Service Robots: Enhancing Productivity and Safety** **Ehsan Asadi**, Co-founder, Director and Principal Scientist, Transforma Robotics, Singapore
1025 – 1040	**The real "Sm@rt Factory"- SEW-EURODRIVE's approach towards Industrie 4.0** **Thilo Grimm**, Managing Director, SEW-Eurodrive, Singapore
1040 – 1055	**Brendel Torsten**, Partner, io-consultants GmbH, Germany
1055 – 1110	Panel Discussion / Q&A
1110 – 1130	*AM Break – L5 Grand Ballroom Foyer*
1130 – 1245	**SESSION 2** **Next Generation Industry and Service Robots** Chair: **Nelson Chang**, Manager, Industrial Technology Research Institute, Taiwan

1130 – 1145	**Recent KUKA Innovations and Future Challenges** **Rainer Bischoff**, Head of Corporate Research, KUKA Roboter, Germany
1145 – 1200	**Human Interaction and Programming of Robots in the Future** **Patric Hed**, Technology Manager, Robots & Applications, ABB Robotics
1200 – 1215	**Beyond the Smart Factory: People and Robots** **Keith Blanchet**, Senior Director, Service Robotics Division, Kinova, Canada
1215 – 1230	**Building Trust with Robots in Service Industries** **David Hanson**, Founder & CEO, Hanson Robotics
1230 – 1245	Panel Discussion / Q&A
1245 – 1345	*Lunch – L5 Grand Ballroom Foyer*
1445 – 1600	**SESSION 3** **IERA Award Presentation** Chairs: **Erwin Prassler** and **Arturo Baroncelli**
1445 – 1500	**Introduction to IERA 2017** **Erwin Prassler**
1500 – 1520	**ANYdrive – a modular joint actuator for advanced interacting robots** **Marco Hunter**, ANYbotics AG
1520 – 1540	**Hunova - an easy to use and intuitive medical device** **Jody Saglia**, Movendo Technology
1540 – 1600	**Sensing flexibility: 3D force and 6-axis force/torque sensors for industrial robotic applications** **György Cserey**, OptoForce
1600 – 1625	*PM Break – L5 Grand Ballroom Foyer*
1625 – 1740	**SESSION 4** **IERA Award Presentation** Chairs: **Erwin Prassler** and **Arturo Baroncelli**
1625 – 1645	**Chairless Chair®** **Sven Liebermeister**, Noonee
1645 – 1705	**Relay autonomous delivery robot** **Steve Cousins**, Savioke
1705 – 1740	Deliberation by jurors

Wednesday - May 31, 2017

Venue: Sands N (Level 5, next to Grand Ballroom)

TIME	SESSIONS
0930 – 1045	**SESSION 5** **Innovations in Human-centric Robotics** Chair: **Zen Koh**, Managing Director, Hocoma Asia Pacific, Singapore
0930 – 0945	**Spiritual Machines** **Chunlin Ji**, Co-founder & Vice President, Kuang-Chi Institute of Advanced Technology, China
0945 – 1000	**The RAMCIP project: Developing a service robot for MCI patients at home** **Dimitrios Giakoumis**, Senior Research Associate, Centre for Research and Technology, Greece
1000 – 1015	**ITRI's Robotic-based Automation Technology for Industrial Applications** **Nelson Chang**, Manager, Industrial Technology Research Institute, Taiwan
1015 – 1030	**Clinical Application of NeuroRehabilitation Robotics** **Zen Koh**, Managing Director, Hocoma Asia Pacific, Singapore
1030 – 1045	Panel Discussion / Q&A
1045 – 1105	*AM Break – L5 Grand Ballroom Foyer*
1105 – 1220	**SESSION 6** **Advanced Autonomous Systems and Devices** Chair: **Paul Tan**, Co-Director, ST Engineering-NTU Corporate Lab, Singapore *Co-organised with ST Engineering*
1105 – 1120	**Managing Demand-driven R&D in Corporate Labs for Successful Translation into Industries** **Paul Tan**, Co-Director, ST Engineering-NTU Corporate Lab, Singapore
1120 – 1135	**Automated Aircraft Inspection Using Unmanned Aerial Systems** **Jia Hui Pang**, Systems Engineer, ST Aerospace, Singapore
1135 – 1150	**Accelerator for AI Computing** **Simon See,** Director, Nvidia Technology Center and Solution Architect and Engineering, Asia Pacific and Japan, Nvidia, Singapore
1150 – 1205	**Role of Competitions in Technology Innovations in Robots** **Lakmal Seneviratne**, Associate Provost of Research and Graduate Studies & Professor of Robotics, Khalifa University, UAE
1205 – 1220	Panel Discussion / Q&A

Industry Forum Speakers

0955 – 1010, Tuesday – May 30, 2017, Sands N (Level 5)

Infrastructure Service Robots: Enhancing Productivity and Safety

Soon Poh Heah

Assistant Chief Executive Officer (Engineering & Operations), JTC, Singapore

JTC, as the lead government agency for the development of industrial infrastructure in Singapore, spearheads innovative space solutions to support and catalyse the growth of new industries and transform existing enterprises. In his address, Mr Heah will share about potential opportunities for the implementation and test-bedding of robotics and automation solutions in Building & Infrastructure projects.

Bio: Soon Poh is the Assistant Chief Executive Officer (Engineering and Operations) at JTC, Singapore's lead government agency responsible for the development of industrial infrastructure to catalyse the growth of new industries and transform existing enterprises. Overseeing the Engineering and Operations Group, Soon Poh is responsible for JTC's engineering design, project management, facility and estate management, as well as security and workplace safety for all JTC's estates and developments.

Soon Poh also oversees JTC's appointment as the public sector's Centre of Excellence for building and infrastructure, facilities management and underground caverns. In the area of facilities management and operations, Soon Poh is leading the implementation of J-Ops, an integrated building and estate management system, across all of JTC's high-rise buildings.

1010 – 1025, Tuesday – May 30, 2017, Sands N (Level 5)

Infrastructure Service Robots: Enhancing Productivity

and Safety

Ehsan Asadi

Co-founder, Director and Principal Scientist, Transforma Robotics, Singapore

The talk is about the application of robots for specific tasks in the construction industry, where robots could attain the required level of autonomy and reliability: interior finishing of industrial developments with high walls and post-construction quality assessment - the motivation, and challenges, as well as current state of our solutions, PictoBot and QuicaBot. Despite the rapid technology evolution,

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construction services are mostly labor-dependent and performed with conventional techniques where safety is always a concern. Beside the low efficiency in this sector, the needs for building, construction and maintenance are growing rapidly all around the world while facing a future shortage of skilled workers and wage increases. It is essential to introduce novel robotic technologies that can be applied to boost productivity by focusing on quality and time saving, as well as to enhance safety and to reduce cost compared to the traditional methods.

Bio: Ehsan Asadi is a co-founder and director at Transforma Robotics, a spin off company from Nanyang Technological University, and serves as principal scientist in robotics. He obtained his B.Sc. and M.Sc. degrees both in Mechanical Engineering and his Ph.D degree in Aerospace Engineering from the Politecnico di Milano, Italy, in 2013. Previously, he has worked as a postdoctoral research fellow at the Robotics Research Center, NTU, Singapore, as well as other research groups and robotics companies including, Poli-rotorcraft, Italy, and Terabee S.A.S, France. His main research interests include sensor fusion, vision-aided inertial navigation, simultaneous localization and mapping, robot vision and field robotics. His involvement in these areas has led to co-authoring of more than 13 papers in refereed journals, international conferences and book chapters. He has served as reviewer for scientific journals and conferences, including the IEEE Transactions in Robotics, Advanced Robotics Systems, ICRA and IROS.

1025 – 1040, Tuesday – May 30, 2017, Sands N (Level 5)

The real "Smart Factory"- SEW-EURODRIVE's

approach towards Industry 4.0

Thilo Grimm

Managing Director, SEW-Eurodrive, Singapore

Interoperability, Virtualization, Decentralization, Real-time capability, Service Orientation, Modularity - these are the design principles of Industrie 4.0. The presentation will give an outlook into SEW-EURODRIVE's holistic approach and enabling technologies according to the design principles of Industrie 4.0.

Bio: Thilo Grimm is Managing Director of SEW-EURODRIVE Pte. Ltd., South-East Asia's Sales, Engineering and Assembly Center of SEW-EURODRIVE. For over 10 years Thilo has focused on business development for Drive Technology in various industries such as Automotive, Food & Beverage, Logistics, Mining, Port Machinery etc. and the specific technological challenges in Asian countries. He has extensive experience in managing innovation and know-how transfer related to Drive Technology in Material Handling and is one of SEW-EURODRIVE's promoters of smart factory solutions. Subsequent to his studies of Chinese language, Thilo received a degree in Engineering from the Cooperative State University Karlsruhe. Further he holds a dual Executive MBA degree from INSEAD, Singapore and TSINGHUA University, Beijing.

Recent KUKA Innovations and Future Challenges

Rainer Bischoff

Head of Corporate Research, KUKA Roboter, Germany

Bio: Dr. Bischoff is Head of KUKA's Corporate Research department responsible for research and technology development preceding product development. Dr. Bischoff received his "Doktor-Ingenieur" degree from Karlsruhe Institute of Technology for his contributions towards the development of personal robots. He serves as Vice-President Industry of euRobotics AISBL – the European Robotics Association he helped to create to unite European roboticists and to engage in a public-private partnership with the European Commission. For leadership and outstanding contributions to the cooperation of academia and industry, and for managing and promoting significant technology transfer in the area of industrial and service robotics he was granted the IEEE Robotics and Automation Society Early Career Award in 2012. In 2015, he received the IROS Toshio Fukuda Young Professional Award for his technical contributions to the personal robotic assistant HERMES and his effort in uniting the European Robotics Community. Dr. Bischoff has authored over 100 papers, receiving three best paper awards. In 2006, Dr. Bischoff received the IEEE/IFR Invention and Entrepreneurship Award for a flexible and scalable collision avoidance system for industrial robots, and in 2012, he was granted the IEEE Robotics and Automation Society Early Career Award for leadership and outstanding contributions to the cooperation of academia and industry, and for managing and promoting significant technology transfer in the area of industrial and service robotics.
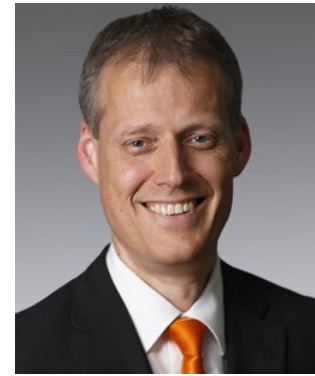
Human Interaction and Programming of Robots in the Future

Patric Hed

Technology Manager, Robots & Applications, ABB Robotics

The landscape of robot programming and human interaction with robots is constantly evolving. Technologies like 3D simulation and offline programming are becoming mainstream tools in the robot industry, while the recent interest in collaborative robots is driving new programming concepts, such as lead-through-teaching. This presentation will also elaborate on opportunities in deploying new technologies in the field of virtual reality and augmented reality for simplified, enhanced and immersive interaction with industrial robots from ABB.

Bio: Patric Hed holds a MSc Degree in Automation and is an international management executive with experience from working with robotics in Sweden, USA, Germany and China. Mr Hed has held a number of positions in the field of robotics over the last 20 years including R&D Manager of ABB Software Products, Engineering Manager of Robot Applications, Global Product Manager of ABB Arc Welding Products, Business Unit Manager at ESAB Welding Automation and he is currently holding the position as Global Technology Manager for Robots & Applications in ABB Robotics.

1200 – 1215, Tuesday – May 30, 2017, Sands N (Level 5)

Beyond the Smart Factory: People and Robots

Keith Blanchet,

Senior Director, Service Robotics Division, Kinova, Canada

The principles of Industry 4.0 are well known. Their current impact on many aspects of product and service offerings, as well as the individual lives of customers, is inevitable. The question is how to best approach this transformation while respecting the human dimension. Job security, "adding value to" instead of "replacing" humans, declared safety vs perceived safety and the knowledge foundations needed to keep workers trained and evolving will all be addressed in this engaging presentation.

Bio: Keith Blanchet holds a bachelor's degree in Mechanical Engineering and an MBA from the Schulich School of Business at York University. His passion for leading-edge technology and innovation has enabled him to collaborate with research and development teams from over 60 countries. Keith has worked in several international markets and has contributed to well-known organisations such as Bombardier DSD (now L-3 MAS) and CAE Marine (now L-3 MAPPS). He has also held key roles at smaller, high-tech start-ups and helped them become global leaders in their respective markets. Most recently, Keith directed international business development for 11 years at Toronto-based Quanser Consulting, a leader in solutions to educate, train and facilitate research for mechatronic and robotic engineers.

Keith has been Senior Director of Kinova Innovation Robotics since the fall, 2016. As a leader of the innovation team, he has worked on developing Kinova's offerings in the fields of IoT, Artificial Intelligence, Big Data and the fusion of a number of sensing technologies. All this in collaboration with researchers from companies including IBM, Google, Facebook, Airbus, Amazon, Boston Dynamics, Walt Disney and Northrop Grumman.

Building Trust with Robots in Service Industries

David Hanson,

Founder & CEO, Hanson Robotics

Robots and intelligent machines are progressing at unprecedented rates, demonstrating great recent leaps in intelligence, perception, expressivity, and the ability to navigate the real world. Humanoid robots will create radical new opportunities in a broad range of commercial applications, including customer service, retail and event promotion, healthcare, education, and entertainment. As humans have an innate preference to perceive faces and empathize with human facial expressions, service robots designed with pleasing aesthetics and a full range of human expressions are in a better position to inspire trust and empathy from the people with whom they interact. These robots will gain faster acceptance, develop richer interaction with people, and drive better results from these interactions, creating significant utilization value for businesses.

Bio: Dr. David Hanson has built a worldwide reputation for creating the world's most humanlike, empathetic robots, endowed with remarkable expressiveness, aesthetics and interactivity. He has produced many renowned, one-of-a-kind robot characters that have received massive media and public acclaim.

Dr. Hanson publishes regularly in materials science, artificial intelligence, cognitive science, and robotics journals, including SPIE, IEEE, the International Journal of Cognitive Science, IROS, AAAI and AI magazine. He has been featured in numerous popular media outlets including New York Times, Popular Science, Scientific American, the BBC and CNN. He has been labeled a "genius" by both PC Magazine and WIRED, and has earned awards from NASA, NSF, AAAI, Tech Titans' Innovator of the Year, and Cooper Hewitt Design Triennial.

At Walt Disney Imagineering, Dr. Hanson worked as both a sculptor and a technical consultant. He has spoken at venues including IEEE, SPIE, AAAI, DARPA, MIT, Dartmouth, Brown, Google, Sandia Labs, UCSD and AAAS annual meeting. Dr. Hanson received his BFA from Rhode Island School of Design in film/animation/video, and his Ph.D. from the University of Texas at Dallas in interactive arts and engineering.

Spiritual Machines

Chunlin Ji

Co-founder & Vice President, Kuang-Chi Institute of Advanced Technology, China

The speaker will introduce Kuang-Chi Global Community of Innovation (GCI) and Prometheus Centre, as well as AI companies, such as eye sight, beyond verbal, agent VI and ElMindA. He will also cover Kuang-Chi products of spiritual machines, bionic land animals, bionic plants and underwater animals which have integrated core AI technology, and the projects under research, jobs opportunities and collaborations.

Bio: Dr Chunlin Ji is the co-founder and vice president of Kuang-Chi Institute of Advanced Technology in Shenzhen, China. He received his BSc Degree from Northeast University in 2003. After that, he got his MSc from Cambridge University and a Ph.D from Duke University in 2009. He then became a research fellow at Harvard University. His research field covers from Bayesian statistics, metamaterial design to communication, and now into robotics and artificial intelligence (AI). Currently, together with his R&D team, he has developed a lot of products such as bionic animals and bionic plants. He is also a trustee of many AI companies and is responsible for the technology part. He has published more than 60 papers and been invited to many conferences in China. He has received several awards, including Special Allowance from the Shenzhen Municipal Government, Shenzhen Overseas High-Calibres Personnel, Core member of the 13th Guangdong May 4th Meal, National Level, Leading Talents in Shenzhen.

The RAMCIP project: Developing a service robot for MCI patients at home

Dimitrios Giakoumis

Senior Research Associate, Centre for Research and Technology, Greece

Dr. Dimitrios Giakoumis will talk about the Robotic Assistant for MCI Patients at home (RAMCIP) – the rationale, motivation and vision for the project, as well as innovations, use cases and the current status of the RAMCIP robot.

Bio: Dr. Dimitrios Giakoumis is a Senior Research Associate in the Information Technologies Institute of CERTH. He received the Diploma in Electrical and Computer Engineering, the M.Sc. in Advanced Computing and Communication Systems and the Ph.D. in Human – Computer Interaction through Affective Interfaces in 2006, 2008 and 2012 respectively, from the Aristotle University of Thessaloniki, Greece. His main research interests include affective computing, robotic perception and cognition, computer vision, human motion, activity and behaviour analysis and modelling, signal processing and

sensor management, multimodal interfaces and pattern recognition. His involvement in these areas has led to co-authoring of more than 35 papers in refereed journals, international conferences and book chapters. He has served as reviewer for a series of scientific journals, including the IEEE Transactions in Biomedical Engineering, Elsevier Computer Methods and Programs in Biomedicine, Computational and Mathematical Methods in Medicine (Hindawi, guest editor of the special issue "Advances in Computational Psychometrics"), the Computer journal (Oxford), the EURASIP Journal on Advances in Signal Processing and Universal Access in the Information Society (Springer), as well as for international conferences; he was the Technical Program Chair of the 5th International Symposium on Pervasive Computing Paradigms for Mental Health (MindCare 2015). He is with CERTH-ITI since 2007 and has been involved in several FP6, FP7 and H2020 R&D projects, as well as in national projects. He is the Quality Assurance Manager of the Horizon2020 RAMCIP project.

1000 – 1015, Wednesday – May 31, 2017, Sands N (Level 5)

Technology Innovation in Robots & Automation

Nelson Chang

Manager, Industrial Technology Research Institute, Taiwan

Industrial 4.0 has been receiving great attention recently. Intelligent robots have been playing a key role in manufacturing. ITRI has been developing robots for both service applications and industrial applications. In this presentation, ITRI will share its experience in industrial robot applications and technology development.

Bio: Nelson Yen-Chung Chang is a department manager in Intelligent Robotics Division, Mechanical and Mechatronics Systems Labs, Industrial Technology Research Institute. He has been working as a senior researcher in robotics vision, research and development manager, and manager of Robot System Integration Department. He majored in VLSI/IC design and was interested in robotic vision. His current research interest is focused on service robot application and technology development.

1015 – 1030, Wednesday – May 31, 2017, Sands N (Level 5)

Clinical Application of NeuroRehabilitation Robotics

Zen Koh

Managing Director, Hocoma Asia Pacific, Singapore

Patients with movement disorder after a damage of the central nervous system can achieve improvement in walking or hand function through intensive, task-specific, and highly repetitive functional training. After a stroke or a spinal cord injury (SCI), neuronal centres at and below the level of lesion exhibit plasticity that can be exploited by functional training paradigms that include assisting stepping or hand/arm movements of the affected side. This session discuss the successful clinical application of robotic devices in the neurorehabilitation for stroke/SCI subjects. Neural mechanisms, afferent feedback, and functional training, for gait and hand/arm movements recovery after stroke/SCI, will be discussed.

Findings from selected clinical studies will also be presented covering the feasibility and efficacy of robot-assisted training using the LokomatPro and Armeo Therapy Concept.

Bio: Zen has extensive experience in providing leadership and management for organisations that provide medical devices, health care solutions and services for people with disabilities, and consults regularly with executives from a variety of fields to help create synergistic solutions. Prior to his current position, he was the Assistant Executive (ACE) for the Singapore National Cooperative Federation (SNCF), which is the apex body for cooperatives in Singapore supporting more than 1.7 million members with total assets of more than S$1.3 billion. He has successfully initiated and launched, as CEO of START Centre, the inaugural International Convention for Rehabilitation Engineering & Assistive Technology in 2007 with Her Royal Highness, Princess Maha Chakri Sirindhorn & Dr Vivian Balakrishnan, the then Minister of Community Development, Youth and Sports as Guest of Honour and Keynote Speakers. Under his leadership, START Centre was awarded the EDB locally based Enterprise Advancement Program on 1st July 2006, receiving fund of up to S$750K, to be the multiplier to promote healthcare, Assistive & Rehabilitative Technology industry for people with disabilities regionally. In June 2012, Zen was nominated by the MD+DI amongst the 40 under 40, future most influential industry leaders in medtech, who are developing novel technologies and leading companies that will transform future healthcare system.

1105 – 1120, Wednesday – May 31, 2017, Sands N (Level 5)

Managing Demand-driven R&D in Corporate Labs for Successful Translation into Industries

Paul Tan

Co-Director, ST Engineering-NTU Corporate Lab, Singapore

Lately, there has been a resurgence of interest in the engineering and technology communities in setting up corporate Research Labs in universities. Although Corporate Labs are not a new concept, the current setups need to be attuned to the exponential pace which technology transformation is taking place today and be more application-oriented to achieve impactful outcomes. To address the opportunities afforded by emerging technologies such as advanced robotics, IoT, artificial intelligence and autonomous systems, this talk aims to share a framework that will allow companies and universities to jointly undertake effective R&D Project Management practices, customer-stakeholder engagement, team development and realistic test-proofing of R&D results in the real world. The purpose is to share some good practices that will help expedite the translation of R&D outcomes to actual commercial application.

Bio: Paul is the Vice President of Technology Development at ST Dynamics - a company in the ST Engineering Group and he also assumes the role of co-Director for the ST Engineering-NTU Robotics Corporate Lab. He has been in the field of engineering for more than twenty years, including sectors such as aerospace, robotics, unmanned vehicles and intelligent systems and is actively involved in the management of advanced R&D in these fields within the company. His current focus is in driving advanced robotics and autonomous systems in the airport and crisis response sectors and believes that there is much opportunity in applying the latest technologies to enhance the operations and safety in these areas.

Automated Aircraft Inspection Using Unmanned Aerial Systems

Jia Hui Pang

Systems Engineer, ST Aerospace, Singapore

During aircraft maintenance, visual inspections are carried out to determine the location and severity of defects, such as cracks, dents, buckles, etc. that may be found on the aircraft bodies. These activities are traditionally done manually, and can be labour-intensive, time consuming, expensive and dangerous to perform. This presentation explores the use of a small, multi-rotor unmanned aerial vehicle (UAV) for automated aircraft inspection in a proof-of-concept trial, and takes a closer look at the key technologies that can be used to enable the UAV to fly autonomously and safely around the aircraft in both indoor and outdoor environments, and to detect and classify defects on the aircraft bodies automatically from the images captured by the UAV.

Bio: Jia Hui is a system engineer with Singapore Technologies Aerospace Ltd. He has eight years of experience designing and developing unmanned aerial vehicles (UAVs) and ground control stations (GCSs) for both military and commercial applications. He graduated from National University of Singapore (NUS) with a Bachelor's Degree in Electrical Engineering, and specialises in electronic, embedded and control system design.

Accelerator for AI Computing

Simon See

Director & Chief Solution Architect, Nvidia, Singapore

The application of Artificial intelligence has been growing exponentially in recent times. This is due to three major facts: availability of data, new algorithms, and democratisation of high-performance computing. In this talk, Dr Simon See will discuss how HPC can help to accelerate the development of new AI algorithm.

Bio: Dr. Simon See is currently the Director and Chief Solutions Architect of NVIDIA Asia Pacific Professional Solution Group. He is also a Professor at the Shanghai Jiaotong University (China) and King-Mong Kung Technical University in Thailand. He is also the Chief Scientific Computing Advisor to BGI (China). Dr See graduated from the University of Salford with a Doctorate degree in Applied Mathematics/Engineering. Prior to joining NVIDIA, he worked for DSO National Lab, IBM, SGI and Sun Microsystems. His research interests are in Computer Architecture and Systems, Simulation and Applied Mathematics. He has published 70+ peer reviewed papers.

1150 – 1220, Wednesday – May 31, 2017, Sands N (Level 5)

Role of Competitions in Technology Innovations in Robots

Lakmal Seneviratne

Associate Provost of Research and Graduate Studies & Professor of Robotics, Khalifa University, UAE

Robotics is a powerful technology with the potential to have a disruptive economic and societal impact. This has resulted in continuing recent major investments in robotics, in anticipation of new market opportunities related to next generation robotics. Many of these new opportunities will require robots to work in crowded, unstructured and dynamic environments, in close proximity to and in collaboration with humans. They will also require the robots to physically interact with the environment, cope with uncertainty, operate with increased autonomy, while maintaining safety. These unsolved robotics problems have also given rise to an increasing number of global robotics competitions. Competitions have the potential to accelerate innovations, provide application focused solutions, while calibrating the gap between expectations and reality. We will review and discuss the role of international competitions in catalyzing future technological innovations in Robotics.

Bio: Lakmal Seneviratne is the founding Director of the Robotics Institute, Associate VP for Research and Professor of Mechanical Engineering at Khalifa University, UAE. He is also the Technical Director of the Mohammed Bin Zayed International Robotics Challenge. Prior to joining Khalifa University, he was Professor of Mechatronics, the founding Director of the Centre for Robotics Research and the Head of the Division of Engineering, at King's College London. His main research interests are centred on robotics and automation, with particular emphasis on increasing the autonomy of robotic systems interacting with complex dynamic environments. He has published over 350 peer reviewed publications on these topics.

Government Forum

There will be three Government Forum sessions at ICRA 2017, each 1h 15mins long. Each session will comprise presentations by three to four speakers, followed by a 15-minute interactive panel discussion with questions and comments from the audience. Satoshi Tadokoro (Tohoku University, Japan) and William R. Hamel (Chair, IEEE RAS Ad Hoc Committee on Governmental Affairs, USA) will also participate in the panel discussions.

Wednesday - May 31, 2017

Venue: Room 4211/4212 (Level 4)

TIME	SESSIONS
0930 – 1045	**SESSION 1** **Investments and National Robotics R&D Direction** Chair: **Kin Huat Low**, Nanyang Technological University, Singapore
0930 – 0950	**An overview of Singapore's National Robotics R&D Programme** **Tong Boon Quek**, Chief Executive, National Robotics Programme, Singapore
0950 – 1010	**Policies and measures for robot development and utilization** **Atsushi Yasuda**, Director, Robotics Policy Office, Manufacturing Industries Bureau, Ministry of Economy, Trade and Industry, Japan
1010 – 1030	**Research in Intelligent Robots and Autonomous Systems at the National Science Foundation** **Reid Simmons**, Program Director, Robust Intelligence, National Robotics Initiative, Smart & Autonomous Systems, CISE/IIS, National Science Foundation, USA
1030 – 1045	Panel Discussion
1045 – 1105	*AM Break – L4 Pre-Function Area*
1105 – 1220	**SESSION 2** **Government and Industry Role in Driving Growth** Chair: **Cecilia Laschi**, Scuola Superiore Sant'Anna, Pisa
1105 – 1125	**Robotics Research in the Engineering Directorate of the US National Science Foundation** **Jordan Berg**, Program Director, National Science Foundation, USA
1125 – 1145	**From Esprit to H2020: 25 years of European support to robot motion research** **Jean-Paul Laumond**, Head of Research, LAAS-CNRS (Team Gepetto), France
1145 – 1205	**ERC - Funding opportunities in Europe for creative minds from anywhere in the world** **Telma Carvalho**, Research Programme Officer, European Research Council

	Executive Agency, European Commission
1205 – 1220	Panel Discussion

1430 – 1545	**SESSION 3** **Bridging the Gap: Government, Academic & Industry** Chair: **Cecilia Laschi**, Scuola Superiore Sant'Anna, Pisa
1430 – 1450	**The Future of Biorobotics in the Fourth Industrial Revolution** **Maria Chiara Carrozza**, Professor of Biorobotics, The Biorobotics Institute, Scuola Superiore Sant'Anna, Italy
1450 – 1510	**The European challenge for promoting large scale, disruptive research initiatives: the Flagship projects on Future Emerging Technologies (FET) and the FLAG-ERA Network of European funding agencies** **Eugenio Guglielmelli**, Professor, Università Campus Bio-Medico, Italy
1510 – 1530	**Robot R&D Direction of Korea** **Kyung-Hoon Kim**, Program Director, MOTIE Intelligent Robot R&D, Korea Evaluation Institute of Industrial Technology, Korea
1530 – 1545	Panel Discussion

Government Forum Speakers

0930 – 0950, Wednesday - May 31, 2017, Room 4211/4212 (Level 4)

An overview of Singapore's National Robotics R&D

Programme

Tong Boon Quek

Chief Executive, National Robotics Programme, Singapore

To bring greater coherency to the robotics-related R&D activities in Singapore, the National Robotics R&D Programme was created under the Research, Innovation and Enterprise (RIE 2015) plan in 2016. This talk will give an overview of the focus and strategy of the NR2P and share examples of R&D projects that have been initiated so far.

Bio: Prof Quek Tong Boon is currently the Chief Scientific Advisor to the Ministry of Trade and Industry and the Chief Executive of the National Robotics Programme as well as Advisor to the Science and Engineering Council (SERC) at A*STAR.

Until 30 June 2016, he was the Chief Defence Scientist of Singapore's Ministry of Defence (MINDEF) and prior to that, he was MINDEF's Deputy Secretary (Technology and Transformation), Chief Research & Technology Officer and the Chief Executive Officer of the DSO National Laboratories.

He is currently a member of the Board of Directors of PUB, Singapore's water agency and a Director on the Board of Temasek Foundation Innovates, a non-profit philanthropic organisation. He has previously served on several other Boards including that of the DSO National Laboratories, the Defence Science and Technology Agency, the Agency for Science, Technology and Research, and the Singapore Technologies Engineering Ltd.

In the higher education sector, his currently serves as a member of the Board of Trustees of the Singapore University of Technology and Design (SUTD) and Advisor to the Provost of NUS. Until 30 June 2016 was also Chairman of the Temasek Laboratories at NUS, NTU and SUTD as well as Chairman of Temasek Defence Systems Institute (TDSI) at NUS and iTrust at SUTD.

He is an Adjunct Professor in the NUS Department of Industrial & Systems Engineering Management.

0950 – 1010, Wednesday - May 31, 2017, Room 4211/4212 (Level 4)

Policies and measures for robot development and utilization

Atsushi Yasuda

Director, Robotics Policy Office, Manufacturing Industries Bureau, Ministry of Economy, Trade and Industry, Japan

An overview of the Japan's "New Robot Strategy" drawn up in 2015 and

the state of actions underway in accordance with the strategy will be presented. Especially, the <u>World Robot Summit</u> planned to be held in Japan in 2020 and Fukushima Robot Testing Field will be mentioned. I'd like to address our policy utilizing robotics competition as an innovation vehicle, with the aim to implement robotics in real daily life/society/industry and accelerate the research and development of robots.

Bio: Atsushi Yasuda is Director of Robotics Policy office in the Ministry of Economy, Trade and Industry (METI) of Japan. In 1998, he entered the METI and engaged in IT policy, innovation policy, climate change policy, and energy policy. He became Director of the Robotics Policy office in 2015 and is in charge of robotics policy. He has a master degree of engineering from Tokyo University and a master degree of public administration from Harvard University.

1010 – 1030, Wednesday - May 31, 2017, Room 4211/4212 (Level 4)

Research in Intelligent Robots and Autonomous

Systems at the National Science Foundation

Reid Simmons

Program Director, Robust Intelligence, National Robotics Initiative, Smart & Autonomous Systems, CISE/IIS, National Science Foundation, USA

This talk will focus on two cross-cutting, inter-disciplinary NSF programs in robotics and autonomous systems. The National Robotics Initiative 2.0 focuses on scaling collaborative robotics towards having them become ubiquitous in society, through coordination between multiple robots, interaction with humans, physical interaction with the environment, and customizable approaches. The Smart and Autonomous Systems program focuses on knowledge-rich, self-aware, self-reliant systems that can learn, adapt, and carry out high-level instructions in a robust and capable manner. Details on these ongoing programs will be presented.

Bio: Reid Simmons is a Research Professor in Robotics at Carnegie Mellon University, currently on leave as a Program Director at the National Science Foundation. He earned his Ph.D. from MIT in 1988 in the field of Artificial Intelligence. Since coming to Carnegie Mellon, Dr. Simmons' research has focused on developing self-reliant robots that can autonomously operate over extended periods of time in unknown, unstructured environments. This work involves issues of robot control architectures that combine deliberative and reactive control, probabilistic planning and reasoning, monitoring and fault detection, and robust indoor and outdoor navigation. His work with NASA on outdoor navigation inspired the algorithms that are used on the Mars rovers. More recently, Dr. Simmons has focused on the areas of human-robot interaction and coordination of multiple heterogeneous robots for assembly. Over the years, Dr. Simmons has published over 200 papers and articles on autonomous robots, robot architectures, HRI, multi-robot coordination, planning and probabilistic reasoning, and has been involved in the development of over a dozen autonomous robots. At NSF, Dr. Simmons is in the

Division of Information and Intelligent Systems of the CISE Directorate, and leads the National Robotics Initiative and Smart and Autonomous Systems programs.

Robotics Research in the Engineering Directorate of the US National Science Foundation

Jordan Berg

Program Director, National Science Foundation, USA

This talk will briefly present current and upcoming programs within the Engineering Directorate of the US National Science Foundation that may be of interest to robotics researchers. These include the existing Dynamics, Control, and System Diagnostics (CMMI/DCSD) program and the Energy, Power, Control, and Networks program (ECCS/EPCN), as well as a new program on human-machine systems called Mind, Machine, and Motor Nexus (CMMI/M3X) and an upcoming robotics opportunity within the Engineering Directorate. The talk will describe the goals of these programs, and suggest ways that interested researchers can align their proposed project topics with those goals.

Bio: Jordan M. Berg received the BSE and MSE in Mechanical and Aerospace Engineering from Princeton University in 1981 and 1984. He worked in the Attitude Control Analysis group at RCA Astro-Electronics in East Windsor, NJ, from 1983 to 1986. He received the PhD in Mechanical Engineering and Mechanics, and the MS in Mathematics and Computer Science from Drexel University in 1992. He has held postdoctoral appointments at the USAF Wright Laboratory in Dayton, OH, and the Institute for Mathematics and Its Applications in Minneapolis, MN. Since 1996 he has been at Texas Tech University, where he is currently Professor of Mechanical Engineering and Co-Director of the Nano Tech Center. As a Fulbright Scholar in 2008 he held visiting faculty appointments at the University of Ruhuna and University of Peradeniya in Sri Lanka. He is a Professional Engineer in the State of Texas and a Fellow of the ASME. In 2014 he was appointed a Program Director for the Sensors, Dynamics, and Controls (SDC) program in the Civil, Mechanical, and Manufacturing Innovation (CMMI) Division of the Engineering (ENG) Directorate at the National Science Foundation, where he is currently serving as an IPA rotator. His current research interests include nonlinear and geometric control, soft robotics, human-machine systems, and the modeling, simulation, design, and control of nano- and microsystems.

From Esprit to H2020: 25 years of European support to robot motion research

Jean-Paul Laumond

Head of Research, LAAS-CNRS (Team Gepetto), France

The talk will focus on the presentation of a sequence of European projects from the 90's to some currrent ones, all of them addressing robot motion technology. From the seminal one (ProMotion running from 1992 to 1995) to the very last one (Actanthrope running from 2014 to 2019), we will see how the topic has evolved and how the support of Europe has been critical.

Bio: Jean-Paul Laumond, IEEE Fellow, is a roboticist. He is Directeur de Recherche at LAAS-CNRS in Toulouse, France. His research is devoted to robot motion. In 2000, he created and managed Kineo CAM, a spin-off company devoted to develop and market motion planning technology. Siemens acquired Kineo CAM in 2012. In 2006, Laumond launched the research team Gepetto dedicated to Human Motion studies along three perspectives: artificial motion for humanoid robots, virtual motion for digital actors and mannequins, and natural motions of human beings. His current project Actanthrope is supported by the European Research Council (ERC). He teaches Robotics at Ecole Normale Supérieure in Paris. He has published more than 150 papers in international journals and conferences in Robotics, Computer Science, Automatic Control and Neurosciences. He has been the 2011-2012 recipient of the Chaire Innovation technologique Liliane Bettencourt at Collège de France in Paris. Laumond is a member of the French Academy of Technologies. He is the 2016 recipient of the IEEE Inaba Technical Award for Innovation Leading to Production.

ERC - Funding opportunities in Europe for creative minds from anywhere in the world

Telma Carvalho

Research Programme Officer, European Research Council Executive Agency, European Commission

The main funding schemes of ERC will be presented together its main achievements in the last 10 years. In particular, it will be highlighted that ERC supports individual researchers at different career development stages of any nationality performing cross disciplinary research pioneering ideas that address new and emerging fields and applications that introduce unconventional and innovative approaches. The portfolio of ERC projects in robotics will be analysed and presented.

Bio: Telma Carvalho received her PhD in Materials Science in 2002 from the Catholic University of Leuven in Belgium. Before joining the European Research Council, she was R&D manager at one of

the spin-off companies of the Catholic University of Leuven developing technologies for assessing material degradation phenomena. At present, she is the coordinator of the panel on "Systems and Communication Engineering" at the European Research Council. The European Research Council funds frontier research that enables breakthrough discoveries and establishes the conditions for future innovations that address key scientific and societal priorities.

1430 – 1450, Wednesday - May 31, 2017, Room 4211/4212 (Level 4)

The Future of Biorobotics in the Fourth Industrial Revolution

Maria Chiara Carrozza

Professor of Biorobotics, The Biorobotics Institute, Scuola Superiore Sant'Anna, Italy

Research, science and social innovation are strictly interdependent, and in this framework, my vision for the future is that progress of humanity is the ultimate mission of science. Today, it is universally accepted in science that challenges of the society will require a strong interdisciplinary effort for scientists.

The integration of robotics with artificial intelligence, deep learning and high speed connection will revolutionize the society because devices will be connected to internet, and will become physically powerful, intelligent and adaptive. Large amounts of data will be available with small latency and *cloud robotics* will share information, data, intelligence activities and brains. Robots were originally designed for manufacturing plants, and nowadays mass production is not possible without robots but now they are indispensable in special environments as space for exploration, oceans for underwater activities or hospitals in surgical rooms. In particular, as it was predicted in science fiction, deep space exploration is now based on robotics, and robots will be essential for space science progress.

The next step will be for robots to enter in our everyday life: in the streets with self-driving cars, or 'at our place' in doing cleaning, entertainment or service activities. Therefore robotics is becoming *'social'*.In order to achieve these goals, engineers must address several issues, related to human-robot interaction, to safety, to sentience and adaptability. The problem of safe, secure and effective *interaction between human being and robot*, cannot be faced without addressing legal and ethical issues.The road map is already in place, with time and application those issues will be studied and investigated, and *robots will share life and environments with humans*, supporting their physical and cognitive activities.Moreover, one of the most fascinating questions to answer in robotics will be originated by the *integration of robotics with bionics and prosthetics*, when robotics will enter into the human body with different levels of invasivity, to support human movements and physical interaction with the environment. *Wearable robotics* is expected to revolutionize the society in the next decade. What are the implications of this transformation of robotics? Which areas of science will be involved in the evolution of robotics? What are the main milestones to be accomplished in the journey of robots from manufacturing plants, to space, health care and ultimately into the human body?

Bio: Maria Chiara Carrozza is an Italian scientist and Member of the National Parliament, Chamber of Deputies, Foreign and European Affairs Committee. From 2007 to 2013 she served as Rector of Scuola Superiore Sant'Anna. In 2013, she was elected Member of the Italian Parliament. From April 28, 2013 until February 2014 she served as Italian Minister for Education and Research. She currently coordinates the NeuroRobotics Area in The Biorobotics Institute at Scuola Superiore Sant'Anna. Since 2016 she is President of the Italian National Group of Bioengineering. In 2016/17 she became Chair of the Panel for the interim Evaluation of FET Flagships Program for the European Commission, DG Communication Networks, Content and Technology. She is Partner of the IUVO, a start-up in wearable robotics founded in 2015 as a spin off of The Biorobotics Institute. Since 2015 she has served on the Board of Directors of the Piaggio Spa group.

1450 – 1510, Wednesday - May 31, 2017, Room 4211/4212 (Level 4)

The European challenge for promoting large scale, disruptive research initiatives: the Flagship projects on Future Emerging Technologies (FET) and the FLAG-ERA Network of European funding agencies

Eugenio Guglielmelli

Professor, Università Campus Bio-Medico, Italy

Since 2010, the European Commission launched the FET-Flagship programme to select and co-fund up to 1 billion euro a limited number of 10-year, disruptive flagship projects on future emerging technologies. Currently, two flagship programmes have been funded and have completed their 3-year ramp-up phase, the Graphene Project and the Human Brain Project. One additional flagship project on Quantum Computing will start this year. More than twenty other candidate flagships are currently competing for being supported in the next 2021-2030 time frame. Some of the current and candidate flagships include robotics & automation topics. A group of funding agencies from all the European Member States promoted a network to provide flagship projects with significant co-funding and promote synergy with other ongoing National and Regional Programmes in order to ultimately gather a critical mass of human capital and innovation resources so to generate a real disruptive impact on science, technology and industry. This talk will briefly present the FET-Flagship programme goals and current status. Then it will specifically report about the ERANET Flag-Era projects and activities, with a specific focus on robotics and automation-related topics currently being addressed by the ongoing flagships, as well as by the candidate proposals to be selected and launched by the end of 2020.

Bio: Eugenio Guglielmelli, IEEE Senior Member, is Professor of Bioengineering at Campus Bio-Medico University of Rome (Italy) where he serves as Prorector for Research and as the Head of the Research Unit of Biomedical Robotics and Biomicrosystems, which he founded in 2004. From 1991 to 2004, he has been with the Advanced Robotics Technology and Systems Laboratory (ARTS Lab, now The BioRobotics Institute) of the Scuola Superiore Sant'Anna in Pisa (Italy), which he also

co-ordinated (2002-2004). His main current research interests are in the fields of human-centred robotics, biomechatronic design and biomorphic control of robotic systems, and in their application to robot-mediated motor therapy, assistive robotics, neuroengineering and neurorobotics. He is the author/co-author of more than 250 papers which have appeared on peer-reviewed international journals, conference proceedings and books. He currently serves as Vice-President for Publication Activities of the IEEE Robotics & Automation Society (RAS), as Member of the Board of Funders of the FET-Flagship European Programme, as member of the Stakeholder Board of the FET FLAGSHIP Human Brain Project, and as the Delegate of the Italian Ministry of Education, University and Research (MIUR) in the Executive Board of the ERANET FLAG-ERA II Programme.

1510 – 1530, Wednesday - May 31, 2017, Room 4211/4212 (Level 4)

Robot R&D Direction of Korea

Kyung-Hoon Kim,

Program Director, MOTIE Intelligent Robot R&D, Korea Evaluation Institute of Industrial Technology, Korea

The Korean government has provided a systematic national promotion in robotics R&D since the establishment of Intelligent Robots Development and Distribution Promotion Act in 2008. For the last nine years, the Korean robot industry has grown 2.6 times in business size, 7.8 times in export and 2.7 times in employment. According to the IFR 2016 report, Korea has become the second largest robot market and has the highest industrial robot density. Despite such intensified robot usage, there has not been a globally renowned robot manufacturer founded in Korea, due to its unique enterprise culture. However, government investment in robot R&D has been effective in maintaining the competitiveness of the manufacturing industry and growing the robot related service industry. Recently, the Korean government has been focusing on the wave of Artificial Intelligence and 4th Industrial Revolution. This presentation will summarize the R&D and promotion strategies that MOTIE is pursuing to strengthen the robot (and overall) industry in Korea.

Bio: Prior to his current position as Program Director of Intelligent Robot at the Korea Evaluation Institute of Industrial Technology (KEIT), Dr Kyung-Hoon Kim was Vice President at Hanwha Techwin (founded as Samsung Techwin). He was with Samsung Techwin for 28 years and involved in numerous aspects of the business, including Industrial Robots, Service Robots (Surveillance) and SMT Equipment Off-Line SW R&D, before becoming Chief of Platform SW Development and SW Engineering then Vice President. Dr Kim holds a Ph.D in Mobile Robot Environment Recognition & Obstacle Avoidance and a master degree from KAIST.

ASEAN & Emerging Country Forum

The ASEAN and Emerging Market Economies, when combined, have very strong growth potential and opportunities for robotics and automation. This is in part due to the large and vibrant population in these countries and their market potential. In the ASEAN & Emerging Country Forum at ICRA 2017, you will learn about the size and potential of the market in the region. Some of the topics and areas of needs and opportunities identified:

- The 4th Industrial Revolution and what it means for the region
- Food security - ASEAN is one of the world's food baskets. Topics include agriculture, fisheries, vertical farming
- Disaster mitigation - Learning from lessons in Fukushima earthquake in Japan and super typhoon Haiyan in the Philippines and how can drones and humanoids help
- Medical and healthcare robotics - The ASEAN and the Emerging Market Economies include some of the most prosperous countries as well as countries that are having economic difficulties at this time. Can innovative medical and healthcare robotics help bridge the disparity in providing affordable health care? How?
- Oil exploration and industrial maintenance - Tied with the rapid industrial developments in these countries is the hunger for energy. How can robotics technologies be used in search for energy sources for the future?
- Frugal innovation - Given the talent and diversity in the region, how can strategies in frugal innovation drive growth in robotics and automation?
- Opportunities for collaboration - The forum will discuss opportunities for scholarships and student exchanges. Initial plans for the formation of ASEAN Robotics Society will be discussed.

Thursday - June 1, 2017

Venue: Room 4211/4212 (Level 4)

TIME	SESSIONS
0930 – 1045	**SESSION 1** **Progress in Robotics and Automation in the ASEAN Region** Chairs: **Marcelo Ang**, National University of Singapore and **John-John Cabibihan**, Qatar University
0930 – 0940	**Singapore** **Marcelo Ang**, National University of Singapore
0940 – 0950	**Malaysia** **Ching Seong Tan**, Multimedia University, Malaysia; Terra-Phoenix Sdn Bhd; iCYCLE Malaysia Sdn Bhd

0950 – 1000	**Philippines** **Laurence Gan Lim**, De La Salle University, Philippines
1000 – 1010	**Thailand** **Mana Saedan**, Chiang Mai University, Thailand
1010 – 1045	Panel Discussion / Q&A
1045 – 1105	*AM Break - L4 Pre-Function Area*
1105 – 1220	**SESSION 2** **Progress in Robotics and Automation in Emerging Market Economies** Chairs: **Marcelo Ang**, National University of Singapore and **John-John Cabibihan**, Qatar University
1105 – 1115	**India** **Prahlad Vaddakeppat**, National University of Singapore
1115 – 1125	**Thailand** **Jackrit Suthakorn**, Mahidol University, Thailand
1125 – 1135	**Turkey** **Erdal Kayacan**, Nanyang Technological University, Singapore
1135 – 1145	**United Arab Emirates** **Lakmal Seneviratne**, Khalifa University, United Arab Emirates
1145 – 1220	Panel Discussion / Q&A

ASEAN members: Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam

Emerging Market Economies: Brazil, Chile, China, Colombia, Greece, Hungary, India, Mexico, Peru, Poland, Qatar, Russia, South Africa, Taiwan, Turkey, United Arab Emirates, including some of the countries in ASEAN.

(Definition: An emerging market economy is a nation's economy that is progressing toward becoming advanced, as shown (1) by some liquidity in local debt and equity markets and (2) the existence of some form of market exchange and (3) regulatory body. List of countries provided by IMF, Dow Jones, etc.)

ICRA-X (Public Forum)

ICRA-X is an outreach activity to the general public in the region that hosts the IEEE International Conference on Robotics and Automation (ICRA) by the IEEE Robotics and Automation Society. It will feature lively presentations from distinguished experts on popular and cutting-edge topics in the field. ICRA-X is aimed at enlightening the greater community, especially the young generation.

Thursday - June 1, 2017   *Grand Ballroom (Level 5)*

TIME	SESSIONS
0930 – 1045	**SESSION 1** **Frontiers of Robotics** Chair: **Ken Goldberg**, UC Berkeley, USA
0930 – 0955	**Ocean One: A Robotic Avatar for Oceanic Discovery** **Oussama Khatib**, Stanford University, USA
0955 – 1020	**The Quest for Natural Machine Motion** **Antonio Bicchi**, University of Pisa & Italian Institute of Technology, Italy
1020 – 1045	**Driving Toward Tomorrow** **Emilio Frazzoli**, Massachusetts Institute of Technology (MIT), USA & Singapore-MIT Alliance for Research and Technology
1045 – 1105	*AM Break – L5 Grand Ballroom Foyer*
1105 – 1220	**SESSION 2** **Innovation and Entrepreneurship** Chair: **Jing Xiao**, University of North Carolina at Charlotte, USA
1105 – 1130	**Additive-generative Industrial Design for Robotic Automation** **Axel Thallemer**, National University of Singapore, Singapore
1130 – 1155	**Essential Ingredients of Building a Successful Robotic Startup** **Zexiang Li**, Hong Kong University of Science and Technology, Hong Kong
1155 – 1220	**Computer Vision and Robotics in the New Era of Digital Agriculture** **Jim Ostrowski**, Blue River Technology, USA

ICRA-X Speakers

Ocean One: A Robotic Avatar for Oceanic Discovery

Oussama Khatib

Stanford University, USA

The promise of oceanic discovery has intrigued scientists and explorers for centuries, whether to study underwater ecology and climate change, or to uncover natural resources and historic secrets buried deep at archaeological sites. A robotic avatar could go where humans cannot, while embodying human intelligence and intentions through immersive interfaces. In collaboration with KAUST, MEKA Robotics, we developed Ocean One, a bimanual force-controlled humanoid robot. With the support of French Ministry of Culture's Underwater Archaeology Research Department, we deployed Ocean One in an expedition in the Mediterranean to Louis XIV's flagship Lune, lying off the coast of Toulon at ninety-one meters. In the spring of 2016, Ocean One became the first robotic avatar to embody a human's presence at the seabed. We foresee that robotic avatars will search for and acquire materials, support equipment, build infrastructure, and perform disaster prevention and recovery operations — be it deep in oceans and mines, at mountain tops, or in space.

Bio: Oussama Khatib received his PhD from Sup'Aero, Toulouse, France, in 1980. He is Professor of Computer Science at Stanford University. His research focuses on methodologies and technologies in human-centered robotics including humanoid control architectures, human motion synthesis, interactive dynamic simulation, haptics, and human-friendly robot design. He is a Fellow of IEEE. He is Co-Editor of the Springer Tracts in Advanced Robotics (STAR) series and the Springer Handbook of Robotics, which received the PROSE Award for Excellence in Physical Sciences & Mathematics. Professor Khatib is the President of the International Foundation of Robotics Research (IFRR). He has been the recipient of numerous awards, including the IEEE RAS Pioneer Award in Robotics and Automation, the IEEE RAS George Saridis Leadership Award in Robotics and Automation, the IEEE RAS Distinguished Service Award, and the Japan Robot Association (JARA) Award in Research and Development.

The Quest for Natural Machine Motion

Antonio Bicchi

University of Pisa & Italian Institute of Technology, Italy

We do not know how robots of the future will look like, but both the layman and the expert agree that they will not be like the heavy, rigid machines we have seen moving clumsily and somewhat

menacingly in the past. Many researchers are indeed focusing on how to build softer robots which can move naturally around in an environment shared with humans.

Gentleness and strength, safety and efficiency, capability and adaptability, smoothness and effectiveness are the contradictory goals that such a naturally moving machine should achieve. In this talk, I will discuss how new materials and design approaches, new sensors and actuators, new control approaches, and new human-robot interfaces can enable the next generation of robots for assisting and cooperating with humans.

Bio: Antonio Bicchi is Senior Scientist with the Italian Institute of Technology in Genoa and Professor of Robotics at the University of Pisa. He graduated from the University of Bologna in 1988 and was a postdoc scholar at MIT AI Lab in 1988–1991. His main research interests are in Robotics, Haptics, and Control Systems. He is the founding Editor-in-Chief of the IEEE Robotics and Automation Letters, and has organized the first WorldHaptics Conference (WHC'05). He co-chaired the Int. Symp. on Robotics Research (ISRR'15), and the Program Committee of the Int. Conf. Robotics and Automation (ICRA'16). He is the recipient of several awards and honors, including an Advanced Grant from the European Research Council for his research on human and robot hands.

1020 – 1045, Thursday - June 1, 2017, Grand Ballroom (Level 5)

Driving Toward Tomorrow

Emilio Frazzoli

Massachusetts Institute of Technology (MIT), USA & Singapore-MIT Alliance for Research and Technology)

How is technology going to change mobility in the future? How will our lives and our cities change as autonomous cars become a reality? In this talk, I will explain the vision that is being pursued by nuTonomy for a future in which safe, reliable, and affordable mobility is provided to all through a fleet of autonomous shared vehicles, augmenting and complementing other transportation options.

Bio: Emilio Frazzoli is a Professor of Dynamic Systems and Control at ETH Zurich, as well as co-founder and CTO of nuTonomy, a startup developing autonomous cars for mobility on demand systems. In acknowledgement of his work in robotics, fleet management, and autonomous systems, Prof. Frazzoli has received numerous major awards, including the the 2015 IEEE George S. Axelby Award and the 2017 IEEE Kiyo Tomiyasu Award. He has published more than 250 papers in the field of robotics, autonomous vehicles, and UAVs. A former full professor at MIT, he directed the research group that put the first autonomous vehicles on the road in Singapore.

Additive-generative Industrial Design for Robotic Automation

Axel Thallemer

National University of Singapore, Singapore

Teaching by research and tutoring Bachelor, Master and Ph.D. students of Industrial Design focusing on low-cost/low-tech robotics with the emphasis on simplicity by smart mechanics powered by artificial muscles co-developed by the speaker for Festo. For both innovation and strategic design management education is shown via case studies how to teach through research in a multidisciplinary manner. Blurring boundaries of professional compartmentalisation and contrary to fragmentation of knowledge are leading towards a new era of innovation by not mimicking nature. Visualisations clearly depict the design process, the managing of both the conceptual development and the alternative morphologies resulting in the final prototypes in comparison to the common industrial solutions. In the presented project this method is being illustrated via pneumatic gripper systems. Three bio-mimetically induced end effectors are designed and protoyped by additive-generative fabrication. Subsequently it is shown, that these three grippers may not be manufactured by traditional production methods.

Bio: Prof. Dipl.-Ing. Axel Thallemer is Full Professor with tenure at National University of Singapore and Deputy Head of Research for Industrial Design. In his fifteen years of employment by industry he designed at R&D center of Porsche, followed by founding and being Head of Festo Corporate Design, afterwards freelance consulting in industrial context. Previous professorships were in Munich, Hamburg and Austria (Dean and Chair of Industrial Design at Linz university, scientifically repositioning Bachelor and Master curricula under the academic brand "scionic®"); currently there are some 16 additional visiting professorships and circa 35 patents. Life Fellow of The RSA in London, founded 1754 and i/IDSA, IEEE, ICED as well as ICoRD and JED reviewer. Member of project group formulating action recommendation "Additive Fabrication" for German Industry on behalf of acatech – German National Academy of Science and Engineering, National Academy of Sciences Leopoldina, Union of the German Academies of Sciences and Humanities.

Essential Ingredients of Building a Successful Robotic Startup

Zexiang Li

Hong Kong University of Science and Technology, Hong Kong

Though the robotics market is estimated to grow at double digits till 2022, and over USD100 million was raised by robotic startups in January 2017, our study reveals that less than 5% of robotic startups last longer than 4 years, and the number is much lower for startups whose primary founders came directly from academia. The major cause leading to the closure of robotic startups is that startups failed to deliver their products to the market in a progressive and constructive manner before using up the resources, especially the monetary investment.

What is the secret code of building a startup in the robotic field, or any hardware field? How to move quickly from lab prototype to pilot production and mass manufacturing? How to effectively manage supply chain that deals with materials, components, modules, and design & manufacturing services? How to organically scale up the teams with co-founders, engineers, technicians, workers and operation staff? How to timely raise funds and get appropriate mentors' guidance? In a nut shell, what are the essential ingredients of building a successful robotic startup?

I believe there is a secret code, or formula to run a robotic startup successfully. In this talk, I unfold the critical challenges exhibited before and during the operation of a robotic startup, and how to tackle these challenges to iteratively make prototypes, test products in the market, collect feedback, analyse and improve the product. I will use some example robotic startups residing in Songshan Lake Robotic Startup facility (Xbot Park) which I founded to illustrate the deployment of the secret code.

Bio: Zexiang Li attended South-Central University in 1978, received his BS degree in EE and Economics from CMU in 1983, then his MS degree in EECS, MA in math and PhD in EECS, all from UC Berkeley. He worked at ALCOA, CMU RI and MIT AI Lab. He was an assistant professor at NYU. In 1992, he joined the ECE Dept of HKUST. He co-founded the Automation Technology Center (ATC) and more recently the HKUST RI. Zexiang Li's major awards include the ALCOA Foundation Fellowship, the E. Anthony Fellowship, the University Scholar award from CMU, the E.I. Jury award from UC Berkeley, and the Outstanding Young Researcher award from NSF China. He became an IEEE Fellow in 2008. Zexiang Li served as an associate editor for the IEEE TRA. He was the general Chair for ICRA'11. Zexiang Li's research areas of interest include a multi-fingered robotic hand, parallel manipulators, work piece localization and inspection, motion control, precision assembly, and UAVs. He is the author of more than 100 journal and conference papers, and the books "A Mathematical Introduction to Robotic Manipulation" (CRC Press 1993), and "Nonholonomic Motion Planning" (Kluwer 1994). Zexiang Li has co-founded several companies with his colleagues and students from the Automation Technology Center, including Googol Technology, DJI, QKM Technology, and ePropulsion. He recently co-founded the Songshan Lake Robotic Startup Center and the Clearwater Bay Venture Capital for robotic startups.

Computer Vision and Robotics in the New Era of Digital Agriculture

Jim Ostrowski

Blue River Technology, USA

The 20th Century saw transformative changes in agriculture, with the introduction of mechanization, the use of new chemistries for fertilization and pest control, and the advent of genetically modified crops. As the demands on food production continue to expand, new technologies are leading to a modern shift into a digital era of agriculture. Along with the increasing use of tools from Data Science, the introduction of Robotics, along with Computer Vision and Machine Learning, are playing a central role in this transformation. This talk will provide an overview of some of these new technologies and describe tools currently being developed and tested that allow farmers to efficiently and economically give plants individual care in order to reduce chemical usage and costs, while at the same time increasing crop yields.

Bio: Dr. Jim Ostrowski is Vice President of Engineering for Blue River Technology, a Sunnyvale-based company working to bring tools from computer vision and robotics to bear in agriculture. Before that, he worked for Evolution Robotics, which later became Evolution Robotics Retail, before being acquired by Datalogic. Jim's field of expertise includes mobile robotics, nonlinear dynamics, and vision-based recognition and control. Prior to joining the start-up world, Jim was at the University of Pennsylvania, where he was a tenured Associate Professor in the Department of Mechanical Engineering and a member of the General Robotics, Sensing, Automation and Perception (GRASP) Laboratory. He holds a Ph.D. in Mechanical Engineering from the California Institute of Technology and an Sc.B. in Electrical Engineering from Brown University. He is a former Associate Editor for the journal IEEE Transactions on Robotics and Automation, was the recipient of the NSF CAREER Young Investigator Award for his work in robotics, and received a Datalogic VIP award for his technical work on the LaneHawk product.

Ethics Forum

The accelerated development of robotics technologies and their permeation in most aspects of our lives in recent years have raised many ethical issues, which are largely debated in the society at large. The purpose of this Ethics Forum at ICRA 2017 is to stimulate the reflection within our robotics community on such questions, in particular

- Are robots 'stealing' jobs from human workers? Do we bear any responsibility in the so-called 'technological unemployment'?
- Are robotic weapons 'ethical'? What are our responsibilities and what role should we play in the societal debates on robotic weapons?

Prominent speakers from academia and NGOs will share their ideas and engage the audience on these questions through their presentations, panel discussion, and interaction with the floor.

Thursday - June 1, 2017

Venue: Room 4211/4212 (Level 4)

TIME	SESSION
1610 – 1725	**ETHICS FORUM** Chair: **Quang-Cuong Pham**, Nanyang Technological University, Singapore Co-Chairs: **Ludovic Righetti**, Max Planck Institute for Intelligent Systems, Germany; **Raja Chatila**, Past President, IEEE RAS (2014 – 2015) & Director of Research, CNRS, France
1610 – 1620	**IEEE global initiative for ethical considerations in AI and autonomous systems** **Raja Chatila**, Past President, IEEE RAS (2014 – 2015) & Director of Research, CNRS, France
1620 – 1635	**Robotics and Anthropomorphism: the need to deconstruct the discourse** **Jean-Paul Laumond**, Director of Research, CNRS (French National Center for Scientific Research)
1635 – 1655	**On the open letter for the ban of autonomous weapons and the survey on impacts of Robotics and AI on jobs** **Toby Walsh**, Professor, University of New South Wales (UNSW), Australia
1655 – 1725	**Panel Discussion** • **Raja Chatila**, Past President, IEEE RAS (2014 – 2015) & Director of Research, CNRS, France • **Toby Walsh**, Professor, UNSW, Australia • **Jean-Paul Laumond**, Director of Research, CNRS, France • **Kerstin Vignard**, Deputy Director and Chief of Operations, UN Institute for Disarmament Research • **Raj Madhavan**, CEO, Humanitarian Robotics Technologies & Chair, IEEE RAS Research and Practice Ethics Committee

Robot Challenges

The Robot Challenges at ICRA 2017 take place on **May 30 - June 1 (morning)**. There are four challenges:

- DJI RoboMasters Mobile Manipulation Challenge
- Humanitarian Robotics and Automation Technology Challenge 2017
- Mobile Microrobotics Challenge 2017
- Soft Material Robot Challenge

Participants for Robot Challenges need to be registered for ICRA 2017. Participants who are only attending ICRA 2017 for the Robot Challenges may register under the **Exhibitor (Team Competition)** category.

DJI RoboMasters Mobile Manipulation Challenge

Organized by: DJI RoboMasters Committee
Website: https://www.robomasters.com/zh-CN/resource/pages/682
Venue: Room 5001-5003 (Level 5)
DJI initiated RoboMasters in 2015 as an educational robotics competition for students around the globe. The annual competition attracted teams who competed on building ground robots that used shooting mechanisms to battle with other robots, and the performance of the robots were monitored by a specially designed judging system. The competition is designed not only to entertain, but also to draw more attention from the general public to robotics. To encourage more participation in shaping the future of robotics, RoboMasters 2017 includes, as a special event, the ICRA 2017 DJI RoboMasters Mobile Manipulation Challenge.
This is a ground robot challenge that examines the application and competence of technologies that include positioning, object grasping, force control, target identification, and system stability. Teams are challenged to develop a lightweight mobile manipulator that can autonomously pick, transport and stack building blocks, and will compete on the bases of completion time and assembly height, while meeting the specified weight and size constraints on the robot.
The competition is suitable for researchers and students with interest and background in autonomous robotic platforms, intelligent navigation and manipulation technologies. The competition is open to everyone around the world regardless of age, nationality and academic qualifications. Participating teams are free to select the components and modules necessary for developing their own robot, and can opt for a RoboMasters mobile base. Finalists stand to win a cash prize and some of the latest innovative products from DJI.

Humanitarian Robotics and Automation Technology Challenge 2017

Organized by:

- Raj Madhavan, HumRobTech LLC; IEEE RAS-SIGHT
- Alexandre Amory, Pontifical Catholic University of Rio Grande do Sul (PUCRS)
- Edson Prestes, Federal University of Rio Grande do Sul (UFRGS)

Website: http://www.inf.ufrgs.br/HRATC2017/
Venue: Room 5202 (Level 5, next to the breaks area)
According to the UN Mine Action Service, landmines kill 15,000–20,000 people every year (mostly children) and maim countless more across 78 countries. Demining efforts cost US$ 300-1000 per mine, and, for every 5000 mines cleared, one person is killed and two are

injured. Thus, clearing post-combat regions of landmines has proven to be a difficult, risky, dangerous and expensive task with enormous social implications for civilians.

Motivated by these considerations, the IEEE Robotics & Automation Society – Special Interest Group on Humanitarian Technology (RAS–SIGHT) is inviting the academic and non-academic community to participate in the second Humanitarian Robotics and Automation Technology Challenge (HRATC) at the 2017 International Conference on Robotics and Automation (ICRA 2017) to be held in Singapore.

Following in the footsteps of the success of the HRATC Challenge that was held at ICRA in consecutive years from 2014 to 2016, this fourth HRATC edition will continue to focus on promoting the development of new strategies for autonomous landmine detection using a mobile (ground) robot.

The Challenge will take place in three phases: 1) Simulation Phase, 2) Testing Phase, and 3) Finals Phase. The strategies developed by the participating teams will be objectively and quantitatively evaluated according to the following criteria: exploration time and environmental coverage; detection and classification quality; and landmine avoidance. Teams will be progressively eliminated after each phase and the remaining teams would move on to the next phase culminating in the Challenge (Finals) phase at ICRA 2017. It should be noted that the teams do not need to purchase or build a robot instrumented with sensors or any of the accompanying software. Every team can participate remotely in each of the phases.

Mobile Microrobotics Challenge 2017

Organized by:

- Aaron T. Ohta, University of Hawaii, Manoa
- Igor Paprotny, University of Illinois, Chicago
- David J. Cappelleri, Purdue University

Website: https://sites.google.com/site/mobilemicrorboticschallenge/
Venue: Room 5101-5103 (Level 5)

The IEEE Robotics & Automations Society (RAS) Micro/Nano Robotics & Automation Technical Committee (MNRA) invites applicants to participate in the 2017 Mobile Microrobotics Challenge (MMC), in which microrobots on the order of the diameter of a human hair face off in tests of autonomy, accuracy, and assembly. Teams can participate in up to three events:

a.   **Autonomous Mobility & Accuracy Challenge:** Microrobots must navigate within a grid of waypoints, fabricated or superimposed on the substrate. At the competition, each team will be given a list of waypoints to hit (targets), and waypoints to avoid (obstacles). The objective is to hit the most targets while avoiding the most obstacles, while moving as rapidly as possible.

   b. **Microassembly Challenge:** Microrobots must assemble a planar shape out of multiple microscale components located in a confined starting region. This task simulates anticipated applications of microassembly for medical or micromanufacturing applications.

   c. **MMC Showcase & Poster Session:** Each team has an opportunity to showcase and demonstrate any advanced capabilities and/or functionality of their microrobot system. Each participating team will get one vote to determine the Best in Show winner.

Soft Material Robot Challenge

Organized by:

- Jian Zhu, National University of Singapore
- Xiangyang Zhu, Shanghai Jiaotong University
- Tiefeng Li, Zhejiang University
- Conor Walsh, Harvard University
- Dónal Holland, University College Dublin
- Robert Shepherd, Cornell University

Website: https://sites.google.com/view/softrobotchallenge2017
Venue: Room 5101-5103 (Level 5)

The Soft Material Robot Challenge invites participants from across the world to demonstrate their robots actuated using soft materials. This challenge provides an international platform to showcase soft robotics research and aims to promote research in the field of soft robotics and applicability to on-field competence. The challenge includes two categories, namely the soft component technologies challenge, and the soft robots speed competition.

a.   **Soft component technologies showcase:** Showcase newly developed soft robot technologies at Soft Component Technologies Challenge. Develop, demonstrate and document a new actuator, sensor or other component technology that advances the field of soft robotics. The entries will be judged for significance, originality, functionality and quality of documentation. The shortlisted entries will be required to demonstrate their prototype at the competition venue in ICRA 2017.

b.   **Soft robots speed challenge:** This section of the challenge aims to pick the fastest robot on land completely driven by soft actuators. The teams are required to abide by the following regulations in designing their robots:
   o   The robotic body should be made of soft materials. Robots which are completely driven by soft actuators are highly encouraged.
   o   The dimensions of the robot cannot be larger than 1m x 1m x 1m.
   o   Teams are free to use on-board or off-board power supply (bonus points for untethered robots -robots with on-board power). Only inlet to 220 V power socket shall be provided. If a team chooses to use off-board power sources, all the wires/conduits connecting to the robot should be slack at all times during the run.

Technical Tours

The following Technical Tours are available as options in the registration form. Please register early as there is limited capacity for all tours. Technical Tours are open to participants across all registration categories. The tour itineraries are subject to changes.

May 29, 2017 (Monday) – 13:00 to 16:00

Cost: SGD 20 per pax
Bus pick up at 12:30 from Marina Bay Sands and returns at 16:00.

- FANUC Tour

June 2, 2017 (Friday) – 09:00 to 17:00

Cost: SGD 60 per pax (lunch and leisure tour to Jurong Bird Park in the afternoon are included)
Bus pick up at 08:15 from Marina Bay Sands and returns at 17:00

- West Tour 1: Visit to NTU RRC, FANUC and Jurong Bird Park
- West Tour 2: Visit to SIMTech @ Valley Block, ARTC, FANUC and Jurong Bird Park
- West Tour 3: Visit to ST Engineering-NTU Corporate Lab, FANUC and Jurong Bird Park
- Central Tour 1: Visit to I^{2}R, SIMTech @ Fusionpolis 2 and Jurong Bird Park
- Central Tour 2: Visit to NUS ARC, HOPE Technik and Jurong Bird Park
- East Tour: Visit to CHART, SUTD and Jurong Bird Park

Technical Tours:

Advanced Remanufacturing and Technology Centre (ARTC)

ARTC is the first centre in Asia that adopts the 'AxRC' model of industry-led public private partnership across supply chains. This unique model is gaining attention from governments and industry globally in recent years. It leverages on a ready pool of resources and R&D funding to achieve technology capabilities and catalyse new business opportunities for all stakeholders.

At ARTC, like-minded companies from multinational corporations to global equipment and software providers to small and medium enterprises come together to collaborate and achieve advanced remanufacturing and manufacturing capabilities in a faster, better and cheaper way than working alone. Based on a membership framework it drives commitment from both industry members and ARTC as active strategic partners in driving a shared capability roadmap.

Through this unique framework industry members are able to solve similar problems on a cost-sharing basis where the best-in- class knowledge is created and shared. In addition, our members can have access to advanced industrial-scale equipment and world-class facility, as well as tap on the extensive industrial research expertise.

Tour participants will be introduced to a range of industrial robots and collaborative robots being utilized for real industrial applications. For more info, please refer to www.a-star.edu.sg/artc.

Centre for Healthcare Assistive & Robotics Technology (CHART)

CHART is a national platform established with the support of the Ministry of Health (MOH) and Singapore Economic Development Board (EDB), that enables healthcare professionals to work closely with industry, academia and research institutions to co-develop and testbed impactful healthcare solutions in assistive technologies and robotics. CHART also works with the National Robotics Programme, a multi-agency initiative to coordinate and support the end-to-end development of robotics technologies. For more info, please refer to

FANUC Singapore Pte Ltd

Participants will be introduced to FANUC and the Singapore showroom with demonstrations of some robots, including the FANUC Robot CR-35iA, a high payload (35kg) collaborative robot that can work without safety fences and stops safely when it touches a human operator; a high speed bin picking system which recognizes 3D locations of multiple parts at a time, allowing the robot to pick items up from a bin within a short amount of time; and a lightweight and compact high speed assembly robot which handles high speed pill sorting system by colour.

Institute for Infocomm Research (I^{2}R)

Participants will visit the A*STAR Social Robotics Laboratory (ASORO), which is part of the robotics department at the I^{2}R under the Agency for Science, Technology and Research (A*STAR). The lab focuses on service and social robot technologies vital to Singapore's industry. You will be able to understand some of the challenges being investigated, including autonomous navigation, robust perception, manipulation, human-robot interaction and cognition. In addition, learn about the research works undertaken to solve the real world challenges faced as part of the smart nation initiative in Singapore, as well as the autonomous vehicle testbed at One North – an approved site for autonomous vehicle testing on actual public roads – and its supporting infrastructure. For more info, please refer to www.i2r.a-star.edu.sg.

Nanyang Technological University (NTU) Robotics Research Centre (RRC)

The RRC has two main research directions: human-centric robots, and infrastructure robotics and automation. With the establishment of LKC Medical School, RRC puts in strong R&D emphasis in healthcare robotics as well as encourage translational projects to benefit Singapore's industry as a whole. A new direction for manufacturing robotics is to have robots work alongside human workers,

rather than working in isolation for the human. The role of these robots is not to replace human workers but to assist human workers in completing tasks with human intelligence and experience. Infrastructure Robotics and Automation as a relatively recent drive for R&D excellence in robotics.

Due to our ageing workforce and also the hazardous nature of civil infrastructure construction, inspection, and maintenance, using robotic technology to assist workers to carry out their tasks becomes a necessity. Robotic equipment that are used for infrastructure applications are often operated outdoors, and the uncertainties present in an outdoor environment make this research area challenging but worthwhile. For more info, please refer to www.rrc.mae.ntu.edu.sg.

National University of Singapore (NUS) Advanced Robotics Center (ARC)

The Advanced Robotics Center (ARC) is an interdisciplinary research centre at the National University of Singapore (NUS). The research at ARC spans a wide spectrum of robotics with a focus on human-centered collaborative robots. ARC aims to advance the state of art in robotics research and partners with Singapore government agencies and industries to translate cutting-edge research into real-world systems. The main laboratory is located on the top floor of a building, with a bird's-eye view of the NUS campus. Participants will go on a tour of robotics facilities at NUS where they will see a number of demos, including autonomous driving, human-robot interaction, robot perception, rehabilitation robotics, soft robotics, etc. You will also be able to ride on various autonomous vehicles from wheelchairs and scooters to cars. For more info, please refer to www.arc.nus.edu.sg.
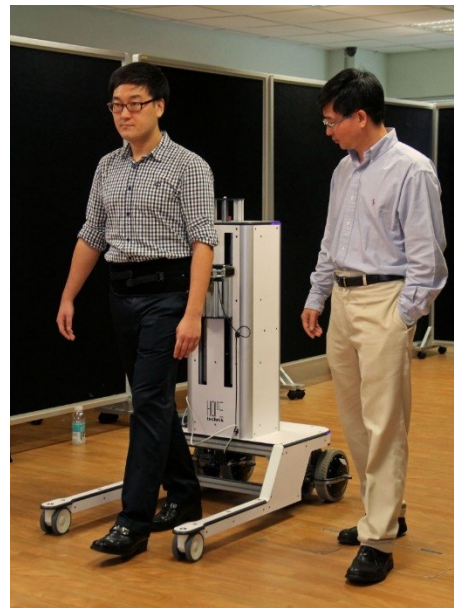
SIMTech @ Fusionpolis 2, Industrial Robotics Lab

Participants will visit the Industrial Robotics Lab of the Singapore Institute of Manufacturing Technology (SIMTech). SIMTech is a research institute of the Agency for Science, Technology and Research (A*STAR). The mission of this lab is to research into and develop key technologies and expertise for the development of industrial robotic systems to tackle difficult-to-automate manufacturing processes. Some of the challenges addressed in this lab include platform technologies for scalable omni-directional mobility systems, robotics for adaptive material removal and robotic modules for precise control of force interactions with the environment.
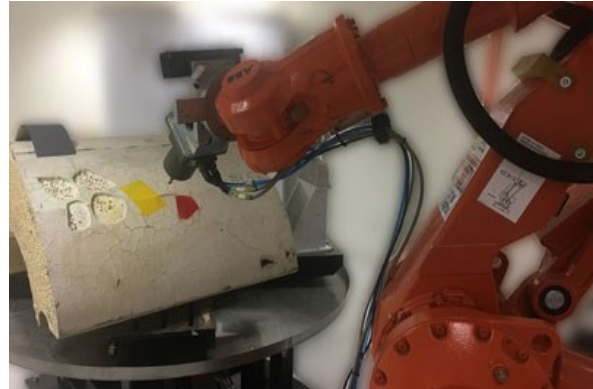
For more info, please refer to www1.simtech.a-star.edu.sg/programmes/research-groups/manufacturing-automation/mechatronics.aspx.

SIMTech @ Valley Block, Robotic Welding Lab

Participants will visit the robotic welding lab at SIMTech @ Valley Block, where the research activities aim to address the issues in welding automation. SIMTech is a research institute of the Agency for Science, Technology and Research (A*STAR). The tour will showcase intuitive robot teaching for welding path, orbital robotic system for large TYK configurations, and automated welding quality assessment and inspection. For more info, please refer to www1.simtech.a-star.edu.sg/programmes/research-groups/manufacturing-automation/mechatronics.aspx.
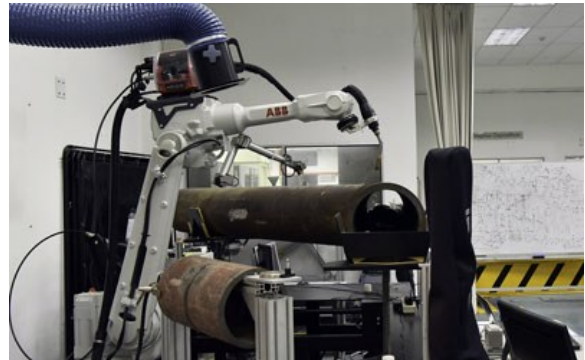
Singapore University of Technology and Design (SUTD) Robotics Innovation Lab (RIL)

RIL is a multi-disciplinary research lab founded in 2013 that focus on robotics innovation in defence, manufacturing and medical. The tour will showcase the various research activities performed by the various robotics research groups located in RIL. Major research activities include bio-inspired robotics design, industrial robotics and assistive robotics. The tour will end with a visit to two of the four antique Chinese buildings donated by film star Jackie Chan, which date back to the Qing and Ming dynasties.

ST Engineering-NTU Corporate Laboratory (STE-NTU Corp Lab)

ST Engineering – NTU Corporate Laboratory is an academics-industry joint research lab that focuses on R&D of relevant technologies for advanced robotic and autonomous systems for applications such as airport gateway and crisis response. Aiming at bringing our research innovation to marketplace, the academics-industry partnership combines both NTU's and ST Engineering's expertise to develop critical technologies in four research areas, namely collaborative teaming, robust autonomous mobility, scene understanding and material handling. Demonstration of various research activities including collaborative multi-robot exploration, UAV precision landing and AI based object detection are to be expected during the tour, such that the participants have a clear overview of the Corp Lab's key capabilities. For more info, please refer to www.ste-ntulab.ntu.edu.sg.
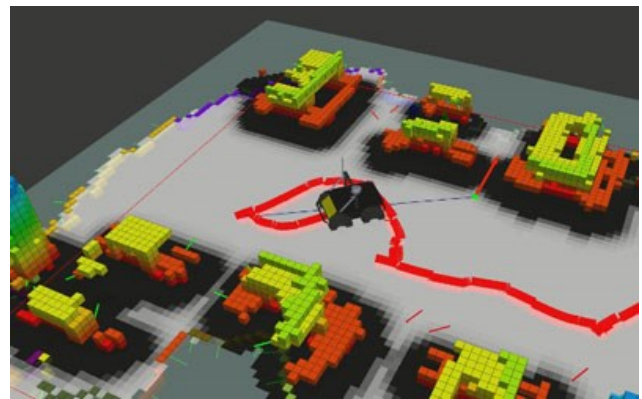
Leisure Tour (Jurong Bird Park) - included in all Friday tours

Charming visitors the world over since taking flight in 1971, Jurong Bird Park is one of the most renowned bird sanctuaries with some of the largest free-flying aviaries in the world. In habitats that mirror their naturalistic environments, Jurong Bird Park is home to the colours of the world, as Asia's largest bird park with a collection of more than 5,000 birds across 400 species.

Our park and its line-up of award-winning exhibits, located at the west-end of Singapore, offers 20.2 hectares of exploratory landscape and gives visitors the opportunity to meet and interact with our feathered residents. For more info, please refer to www.birdpark.com.sg.

Awards

- Best Conference Paper Award (TuC9)
- Best Student Paper Award (TuD9)
- Best Automation Paper Award (WeA11)
- Best Cognitive Robotics Paper Award (WeA6)
- Best Medical Robotics Paper Award (TuB10)
- Best Robotic Manipulation Paper Award (WeB7)
- Best Robotic Vision Paper Award (TuA3)
- Best Service Robotics Paper Award (WeB11)
- Best Human-Robot Interaction (HRI) Paper Award (TuB8)
- Best Multi-Robot Systems Paper Award (TuA5)
- ICRA CEB award for Best Associate Editors
- ICRA CEB award for Best Reviewer

Best Conference Paper Award (TuC9)

FINALISTS

- **The Robotarium: A Remotely Accessible Swarm Robotics Research Testbed**
  Pickem, Daniel; Glotfelter, Paul; Wang, Li; Mote, Mark; Ames, Aaron; Feron, Eric; Egerstedt, Magnus

- **Design, Development and Experimental Assessment of a Robotic End-Effector for Non-Standard Concrete Applications**
  Kumar, Nitish; Hack, Norman; Doerfler, Kathrin; Walzer, Alexander Nikolas; Rey, Gonzalo Javier; Gramazio, Fabio; Kohler, Matthias Daniel; Buchli, Jonas

- **Information Theoretic MPC for Model-Based Reinforcement Learning**
  Williams, Grady; Wagener, Nolan; Goldfain, Brian; Drews, Paul; Rehg, James; Boots, Byron; Theodorou, Evangelos

- **Probabilistic Data Association for Semantic SLAM**
  Bowman, Sean; Atanasov, Nikolay; Daniilidis, Kostas; Pappas, George J.

- **Estimating Unknown Object Dynamics in Human-Robot Manipulation Tasks**
  Cehajic, Denis; Budde genannt Dohmann, Pablo; Hirche, Sandra

Best Student Paper Award (TuD9)

FINALISTS

- **Data-Driven Design of Implicit Force Control for Industrial Robots**
  Parigi-Polverini, Matteo; Formentin, Simone; Dao, Le Anh; Rocco, Paolo

- **Motion Planning with Movement Primitives for Cooperative Aerial Transportation in Obstacle Environment**
  Kim, Hyoin; Lee, Hyeonbeom; Choi, Seungwon; Noh, Yung-Kyun; Kim, H. Jin

- **1-Actuator 3-DoF Parts Feeding Using Hybrid Joint Mechanism with Twisted Axis Layout**
  Sakashita, Ryohei; Higashimori, Mitsuru

- **Robust Policy Search with Applications to Safe Vehicle Navigation**
  Sheckells, Matthew; Garimella, Gowtham; Kobilarov, Marin

- **Autonomous Robotic Stone Stacking with Online Next Best Object Target Pose Planning**
  Furrer, Fadri; Wermelinger, Martin; Yoshida, Hironori; Gramazio, Fabio; Kohler, Matthias Daniel; Siegwart, Roland; Hutter, Marco

Best Automation Paper Award (WeA11)

<u>**FINALISTS**</u>

- **A Distributed Approach to Automated Manufacturing Systems with Complex Structures Using Petri Nets**
  Yang, Yan; Hu, Hesuan; Liu, Yang

- **UAV-Based Crop and Weed Classification for Smart Farming**
  Lottes, Philipp; Khanna, Raghav; Pfeifer, Johannes; Siegwart, Roland; Stachniss, Cyrill

- **NimbRo Picking: Versatile Part Handling for Warehouse Automation**
  Schwarz, Max; Milan, Anton; Lenz, Christian; Munoz, Aura; Periyasamy, Arul Selvam; Schreiber, Michael; Schüller, Sebastian; Behnke, Sven

- **Planning and Executing Optimal Non-Entangling Paths for Tethered Underwater Vehicles**
  McCammon, Seth; Hollinger, Geoffrey

- **Peduncle Detection of Sweet Pepper for Autonomous Crop Harvesting - Combined Colour and 3D Information**
  Sa, Inkyu; Lehnert, Christopher; English, Andrew; McCool, Christopher Steven; Dayoub, Feras; Upcroft, Ben; Perez, Tristan

Best Cognitive Robotics Paper Award (WeA6)

<u>**FINALISTS**</u>

- **Deep Visual Foresight for Planning Robot Motion**
  Finn, Chelsea; Levine, Sergey

- **Deep Multimodal Embedding: Manipulating Novel Objects with Point-Clouds, Language and Trajectories**
  Sung, Jaeyong; Lenz, Ian; Saxena, Ashutosh

- **Learning to Represent Haptic Feedback for Partially-Observable Tasks**
  Sung, Jaeyong; Salisbury, Kenneth; Saxena, Ashutosh

- **Learning to Guide Task and Motion Planning Using Score-Space Representation**
  Kim, Beomjoon; Kaelbling, Leslie; Lozano-Perez, Tomas

Best Medical Robotics Paper Award (TuB10)

<u>**FINALISTS**</u>

- **Magnetically Actuated Soft Capsule Endoscope for Fine-Needle Aspiration Biopsy**
  Son, Donghoon; Dogan, Mustafa Doga; Sitti, Metin

- **Preliminary Results on Energy Efficient 3D Prosthetic Walking with a Powered Compliant Transfemoral Prosthesis**
  Huihua, Zhao; Ambrose, Eric; Ames, Aaron

- **A Rolling-Diaphragm Hydrostatic Transmission for Remote MR-Guided Needle Insertion**
  Burkhard, Natalie; Frishman, Samuel; Gruebele, Alexander; Whitney, John Peter; Goldman, Roger E.; Daniel, Bruce; Cutkosky, Mark

- **First Demonstration of Simultaneous Localization and Propulsion of a Magnetic Capsule in a Lumen using a Single Rotating Magnet**
  Popek, Katie; Hermans, Tucker; Abbott, Jake

- **Efficient Proximity Queries for Continuum Robots on Parallel Computing Hardware**
  Leibrandt, Konrad; Yang, Guang-Zhong

Best Robotic Manipulation Paper Award (WeB7)

<u>**FINALISTS**</u>

- **Optimal, Sampling-Based Manipulation Planning**
  Schmitt, Philipp Sebastian; Neubauer, Werner; Feiten, Wendelin; Wurm, Kai M.; v. Wichert, Georg; Burgard, Wolfram

- **Design of a Simplified Compliant Anthropomorphic Robot Hand**
  Wiste, Tuomas; Goldfarb, Michael

- **Integrating Motion and Hierarchical Fingertip Grasp Planning**
  Haustein, Joshua Alexander; Hang, Kaiyu; Kragic, Danica

- **Analyzing Achievable Stiffness Control Bounds of Robotic Hands with Compliantly Coupled Finger Joints**
  Rao, Prashant; Thomas, Gray; Sentis, Luis; Deshpande, Ashish

- **A Two-Fingered Robot Gripper with Large Object Reorientation Range**
  Bircher, Walter; Dollar, Aaron; Rojas, Nicolas

Best Robotic Vision Paper Award (TuA3)

<u>**FINALISTS**</u>

- **Probabilistic Data Association for Semantic SLAM**
  Bowman, Sean; Atanasov, Nikolay; Daniilidis, Kostas; Pappas, George J.

- **A Comparative Analysis of Tightly-Coupled Monocular, Binocular, and Stereo VINS**
  Paul, Mrinal Kanti; Wu, Kejian; Hesch, Joel A.; Nerurkar, Esha; Roumeliotis, Stergios

- **SE3-Nets: Learning Rigid Body Motion using Deep Neural Networks**
  Byravan, Arunkumar; Fox, Dieter

- **Probabilistic Articulated Real-Time Tracking for Robot Manipulation**
  Garcia Cifuentes, Cristina; Issac, Jan; Wüthrich, Manuel; Schaal, Stefan; Bohg, Jeannette

- **Self-supervised Learning of Dense Visual Descriptors**
  Schmidt, Tanner; Newcombe, Richard; Fox, Dieter

Best Service Robotics Paper Award (WeB11)

<u>**FINALISTS**</u>

- **Improving Octree-Based Occupancy Maps using Environment Sparsity with Application to Aerial Robot Navigation**
  Chen, Jing; Shen, Shaojie

- **Feasibility study of IoRT platform "Big Sensor Box"**
  Kurazume, Ryo; Pyo, Yoonseok; Nakashima, Kazuto; Tsuji, Tokuo; Kawamura, Akihiro

- **Autonomous Robotic System using Non-Destructive Evaluation methods for Bridge Deck Inspection**
  Le, Tuan; Spencer, Gibb; Pham, Nhan; La, Hung; Logan, Falk; Tony, Berendsen

- **High-Precision Microinjection of Microbeads into C. Elegans Trapped in a Suction Microchannel**
  Nakajima, Masahiro; Ayamura, Yuki; Takeuchi, Masaru; Hisamoto, Naoki; Pastuhov, Strahil; Hasegawa, Yasuhisa; Fukuda, Toshio; Huang, Qiang

Best Human-Robot Interaction (HRI) Paper Award (TuB8)

<u>**FINALISTS**</u>

- **Simulating Gait Assistance of a Hip Exoskeleton: Case Studies for Ankle Pathologies**
  Lim, Bokman; Hyung, SeungYong; Lee, Jusuk; Seo, Keehong; Jang, Junwon; Shim, Youngbo

- **Mobile Robot Companion for Walking Training of Stroke Patients in Clinical Post-Stroke Rehabilitation**
  Gross, Horst-Michael; Meyer, Sibylle; Scheidig, Andrea; Eisenbach, Markus; Mueller, Steffen; Trinh, Thanh Quang; Wengefeld, Tim; Bley, Andreas; Martin, Christian; Fricke, Christa

- **Estimating unknown object dynamics in human-robot manipulation tasks**
  Cehajic, Denis; Budde genannt Dohmann, Pablo; Hirche, Sandra

- **Development of a Block Machine for Volleyball Attack Training**
  Sato, Kosuke; Watanabe, Keita; Mizuno, Shuichi; Manabe, Masayoshi; Yano, Hiroaki; Iwata, Hiro

- **Hierarchical Cascade Controller for Assistance Modulation in a Soft Wearable Arm Exoskeleton**
  Dinh, Binh Khanh; Xiloyannis, Michele; Antuvan, Chris Wilson; Cappello, Leonardo; Masia, Lorenzo

Best Multi-Robot Systems Paper Award (TuA5)

<u>**FINALISTS**</u>

- **Distributed Data Gathering with Buffer Constraints and Intermittent Communication**
  Guo, Meng; Zavlanos, Michael M.

- **The Robotarium: A Remotely Accessible Swarm Robotics Research Testbed**
  Pickem, Daniel; Glotfelter, Paul; Wang, Li; Mote, Mark; Ames, Aaron; Feron, Eric; Egerstedt, Magnus

- **Decentralized Non-communicating Multiagent Collision Avoidance with Deep Reinforcement Learning**
  Chen, Yufan; Liu, Miao; Everett, Michael; How, Jonathan Patrick

- **Decentralized Matroid Optimization for Topology Constraints in Multi-Robot Allocation Problems**
  Williams, Ryan; Gasparri, Andrea; Ulivi, Giovanni

- **Formations for Resilient Robot Teams**
  Guerrero-Bonilla, Luis; Prorok, Amanda; Kumar, Vijay

Workshops and Tutorials

Access to the workshops/tutorials will be strictly controlled and only delegates with valid badges/passes will be allowed entry to the respective areas. **Lunch and coffee breaks are included** in the registration fee for workshops/tutorials.

- **Coffee breaks:** 10:00 – 10:30 (AM) / 15:00 – 15:30 (PM)
- **Lunch break:** 12:00 – 13:30

Monday - May 29, 2017

Full Day Workshops: 08:30 – 17:00

Title	Organizers
Advances and Challenges on the Development, Testing and Assessment of Assistive Robots: Experiences from Engineering and Human Science Research	J. Solis, Y. Takeda, E. Tanaka, A. Frisoli
Second Workshop on: Robust Perception, Planning, and Control for Legged Robot Locomotion in Challenging Domains	D. Kanoulas, I. Havoutis, M. Fallon, A. Del Prete, E. Yoshida
Sensor-Based Object Manipulation for Collaborative Assembly	M. Li, H. Ding, Q. Li, Z. Chen
Warehouse Picking Automation Workshop 2017: Solutions, Experience, Learnings and Outlook of the Amazon Picking Challenge	A. Causo, J. W. Durham, K. Okada, K. Hauser, A. Rodriguez
Advanced Fabrication and Morphological Computation for Soft Robotics	C. Laschi, K. Hosoda, J. Wei, P. Valdivia y Alvarado, S. G. Nurzaman, F. Iida
Autonomous Structural Monitoring and Maintenance using Aerial Robots	K. Alexis, M. W. Achtelik, G. Antonelli, M. Chli, A. Ollero, R. Siegwart, K. Valavanis
The Robotic Sense of Touch: From Sensing to Understanding	S. Somlor, A. Schmitz, L. Jamone, L. Natale, G. Cheng
Recent Advances in Dynamics for Industrial Applications	J. Pan, Y. Wu, F. Park
AI Planning & Robotics: Challenges and Methods	J. C. Beck, A. Finzi, N. Hawes, A. Orlandini, G. Nejat
Mechanics of Human Locomotion and the Development of Wearable Robotic Systems	E. Rouse, H. Lee, H. Vallery, P. Artemiadis
Reproducible Research in Robotics: Current Status and Road Ahead	F. P. Bonsignorio, S. Redfield, A. P. del Pobil

Half Day Tutorials: 8:30 – 12:00 (AM) / 13:30 – 17:00 (PM)

Title	Organizers
Tutorial on AI Planning for Robotics (AM)	D. Magazzeni, M. Cashmore
Buzz: A Programming Language for Multi-Robot Systems (PM)	C. P. Giovanni Beltrame

Friday - June 2, 2017

Full Day Workshops: 08:30 – 17:00

Title	Organizers
Human Multi-Robot Systems Interaction	Y. Wang, A. Franchi, N. Ayanian, L. Sabattini, R. Fitch
Biohybrid Machine by Small-scale Robotics and Systems	M. Nakajima, K. Morishima, H. Sato, T. Fukuda, M. Sitti, S. Bergbreiter, L. Ricotti
Learning and Control for Autonomous Manipulation Systems: The Role of Dimensionality Reduction	F. Ficuciello, S. Calinon, P. Falco
Disaster Response Robots: Design Principles and Control for Effective Mobility and Manipulation	N. Tsagarakis, P. Ogren, P. Jensfelt, S. Behnke
Assistive Robotics: From the Natural to the Artificial and Back Again	A. Ajoudani, K. Y. Cho, T. Flash, E. Schearer
Innovative Haptic Interfaces Emerging from Soft Robotics	H. A. Wurdemann, M. Srinivasan, K. Althoefer, C. Laschi, A. M. Okamura, Y. Zhang, Y. Zhang, V. Pawar
Multi-robot Perception-Driven Control and Planning	J. Alonso-Mora, E. Montijano, D. Rus, M. Schwager
Event-based Vision	D. Scaramuzza, A. Censi, G. Gallego
AI in Automation	K. Harada, D. Manocha, K. Goldberg
C4 Surgical Robots: Compliant, Continuum, Cognitive, and Collaborative	H. Ren, C. Bergeles, P. Dupont, P. Poignet, A. Garg, C. Liu, R. Alterovitz, M. C. Yip
Robotics and Vehicular Technologies for Self-Driving Cars	M. H. Ang Jr, D. Hsu, D. Rus, C. Laugier, M. Meghjani
IC3 - Industry of the Future: Collaborative, Connected, Cognitive. Novel Approaches Stemming from Factory of the Future & Industry 4.0 Initiatives	P. Dario, A. Knoll, L. Seneviratne, M. Maffei, A. Baroncelli

Workshop

Advances and Challenges on the Development, Testing and Assessment of Assistive and Rehabilitation Robots: Experiences from Engineering and Human Science Research

ABSTRACT

Assistive robots for health and welfare applications are required to display perceptual, cognitive and bodily-kinaesthetic capabilities that are natural and intuitive for older people and persons with disabilities to interact with, communicate with, work with as partners, and learn to adapt to their needs. However, the embodiment of such capabilities has been scarcely studied, so it is still required that the health and social care staff and the user groups could explore and learn how to exploit the capabilities of the assistive robots. Therefore, a multidisciplinary approach to promote the study from the engineering and human science to introduce the next generation of assistive robots is desired. The goal of this workshop is to provide a forum for sharing the experiences from the engineering and human science research on the development, testing and assessment of assistive robots and present the most recent advances and challenges in order to foreseen novel designing approaches and user based studies addressing healthcare and social welfare applications in the ambient assisted living from a world-wide perspective with point of departure in interdisciplinary research collaboration.

ORGANIZERS

- **Jorge Solis, Ph.D.** (primary contact person)
  Associate Professor
  Karlstad University, Sweden
  URL: https://www5.kau.se/en/electrical-engineering/robotics/
- **Yukio Takeda, Ph.D.**
  Professor
  Tokyo Institute of Technology, Japan
  URL: http://www.mech.titech.ac.jp/~msd/en/
- **Antonio Frisoli, Ph.D.**
  Associate Professor
  Scuola Superiore Sant'Anna, Italy
  URL: http://percro.sssup.it/~antony/
- **Eiichiro Tanaka, Ph.D.**
  Professor
  Waseda University, Japan
  URL: https://www.waseda.jp/fsci/gips/other-en/2016/03/29/5670/

Website: https://www.kau.se/icra2017

Robust Perception, Planning, and Control for Legged Robot Locomotion in Challenging Domains

OBJECTIVE

Recent advances in perception, planning, and control have enabled legged robots to successfully navigate in environments that are mostly known or well-structured and modeled. The DARPA Robotics Challenge (DRC) 2015 showed that **in** real-world unstructured and uncertain environments robots often lack robustness with regards to locomotion. From one side, this may be due to modeling uncertainties and actuation inaccuracies that affect the control

loops. From the other side, both proprioceptive and exteroceptive perception and planning are crucial for detecting foothold and handhold affordances in the environment, and generating agile motions accordingly.

This workshop will provide a platform for researchers from perception**,** planning**,** and control in legged robotics to disseminate and exchange ideas, evaluating their advantages and drawbacks. This will include methods for robust control/planning optimization, such as Model Predictive Control, as well as path planning and perception methods for detecting footholds and handholds on challenging surfaces for legged robots including bipeds and quadrupeds. The goal is to show various ways from sensing the environment to finding contacts and planning/controlling the body and limb trajectories for achieving agile and robust locomotion. The aim is to foster collaboration among researchers that are working on legged robots to advance the state of the art in robot locomotion.

This full day workshop consists of a mixture of presentations on topics including sensing, perception, planning, motion generation, and control for various types of legged robots designed to work indoors and outdoors. To stimulate interaction, we also organize a poster session to encourage the participation of young researchers and promote discussion with the speakers and the audience. Moreover, we allocate adequate time for questions and discussion to make the workshop as interactive as possible.

ORGANIZERS

- **Dr. Dimitrios Kanoulas**, *ADVR, Istituto Italiano di Tecnologia (IIT)* [Italy].
- **Dr. Ioannis Havoutis**, *IDIAP Research Institute* [Switzerland].
- **Prof. Maurice Fallon**, *School of Informatics, University of Edinburgh* [UK]**.**
- **Dr. Andrea Del Prete,** *LAAS-CNRS* [France]**.**
- **Dr. Eiichi Yoshida**, *National Institute of Advanced Industrial Science and Technology (AIST)* [Japan]**.**

Website: https://icra2017wslocomotion.wordpress.com/

Sensor-Based Object Manipulation for Collaborative Assembly

ABSTRACT
Object manipulation encompasses a large variety of research activities, from grasping to fine manipulation. During the past decade, the interests in robot object manipulation have developed, from basic researches broad industry profiles, from physics-based modeling to sensor-based learning, from stand-alone robot applications to human robot collaboration. The driving force behind this shift is the vision that many practical robot applications, such as assembly, including inevitable modeling uncertainties, which require the use of sensor-based approaches to design reactive skills for robots. Moreover, these tasks are still difficult to be accomplished with robots alone, and need combination of the flexibility of human workers and the productivity of robots. In order to improve the collaborative assembly capabilities and efficiency, we need to answer following questions.
1) What kind of control strategies and end-effectors are needed in robot assembly tasks? How can we achieve and improve it?
2) How to model the cooperation between human and robots so that the assembly task can be implemented in an optimal way?
3) How to represent the collaborative assembly tasks in order to leverage the power of learning to design efficient controllers?
The aim is to bring researchers from both industry and academia to set the basis and define core open problems for collaborative assembly, such as planning, control, learning, design and

perception. This workshop will also discuss advantages, limitations, challenges and progress with different approaches along these lines.

The workshop topics include (but are not limited to) the following:

- Task planning for collaborative assembly
- Robots' hardware optimization for collaborative application
- Control strategy for object manipulation/ collaborative assembly
- Learning the object manipulation skill from human demonstration
- Improving the object manipulation skill by exploration learning
- Integrate haptic perception and vision for collaborative assembly
- In-hand object manipulation
- Sensor fusion based on tactile, force and vision feedback

ORGANIZERS

- **Miao Li,** Associate Professor, Wuhan University, China, (086)15527576906, Email: limiao712@gmail.com
- **Hao Ding**, Principal Scientist & Project Lead, ABB Corporate Research Germany, Address: Wallstadter Str. 59, 68526 Ladenburg, Germany; Phone: +49 6203 71-6028; Email: hao.ding@de.abb.com
- **Qiang Li**, Senior Researcher, Bielefeld University, Germany, Email: qli@techfak.uni-bielefeld.de
- **Zhaopeng Chen,** Senior Researcher, German Aerospace Center, DLR, Germany, Phone: +49 8153 28 1397; Email: zhaopeng.chen@dlr.de

Website: https://sites.google.com/view/somca

Warehouse Picking Automation Workshop 2017: Solutions, Experience, Learnings and Outlook of the Amazon Robotics Challenge

The launch of the Amazon Robotics Challenge (formerly the Amazon Picking Challenge) in 2015 has shone light on the challenging problem of item picking in an e-commerce fullfilment warehouse. We have seen a lot of developments on all aspects of the picking problem since then. The challenges of automated item picking is a quintessential robot problem that encompass various aspects of grasping, vision and other forms of sensing, gripper and robot design, motion planning, optimization, machine learning, software engineering, and system integration, among others.

The main aim of this workshop is to gather past and future participants of The Challenge and the robotics and automation community to discuss their robotic solutions, experience of the previous competitions and their vision on automating item picking for warehouse logistics. Attendees of the workshop will have the opportunity to see the state-of-the-art in item picking research and development and interact with the people who are passionate about solving this complex problem during the presentations, poster discussions, and open forums. This workshop is co-organized by Amazon Robotics, the sponsor of the Amazon Robotics Challenge.

TOPICS

- Robotic Solutions
  The systems that could automatically pick items from inventory storage. The sub-systems (hardware design and software integration) that make up the whole solution and the integration process and lessons learned in building them.
- Grasp Strategy and Gripper Design
  The challenges of picking from a space-constrained shelf; The end-effector hardware designed, fabricated, and tested to address the problem; The processes, algorithms, and strategies to successfully pick target items.
- Perception
  The challenges of item identification and pose estimation in such a cluttered and constrained environment; The vision systems and other complementary sensors required to build a system to support the perception strategy; The perception strategy and algorithms leveraged or developed to correctly pick the target items; The advantages and disadvantages of some sensors & cameras over others.
- Strategy & Integration
  The rationale for the design of the competition; The identification of the sub-problems that define the grand problem of automated item picking in a warehouse; Strategies (hardware, software, or process) to overcome the engineering problems; The optimization strategies on planning and control to achieve a safe and efficient solution.
- Journey to Winning The Competition & Solving the Engineering Challenges
  The teams' strategies to win the Amazon Robotics Challenge; The challenges of building a technical team and solving a complex problem within a short period of time; The trade-offs required and the milestones set to be able to build a competition-ready solution. The future outlook of the competition and the item-picking problem as an academic and industrial pursuit.

ORGANIZERS

- **Albert Causo**
  Research Fellow, Robotics Research Centre
  Nanyang Technological University, Singapore
- **Joey Durham**
  Manager, Research & Advance Development
  Amazon Robotics
- **Kei Okada**
  Associate Professor, JSK Laboratory
  The University Of Tokyo
- **Kris Hauser**
  Associate Professor, Department of Electrical and Computer Engineering
  Duke University
- **Alberto Rodriguez**
  Assistant Professor, Department of Mechanical Engineering
  Massachusetts Institute of Technology

Website: http://wpaw17.kawso.com/

Workshop on Advanced Fabrication and Morphological Computation for Soft Robotics

Sponsored by National Robotics Programme, Singapore

OBJECTIVE

Advances in Soft Robotics are leading to increasingly challenging designs in terms of desired geometries, material distributions, and functionality. Traditional sequential casting and additive manufacture approaches present various limitations for fabrication and new techniques are needed. Furthermore, new available structural functionality presents a tremendous opportunity for new techniques in morphological computation, i.e. the way computation, control, and sensing are facilitated by the robot's morphology which may include its shape, deformability and material properties. Recent advances in fabrication techniques and morphological computation are poised to further expand application areas, performance, as well as the impact of Soft Robots.

This workshop aims to present the latest advances in the fields of fabrication and morphological computation for soft robotics. Talks will describe new and novel ideas in both fields and various ways in which they can be applied to the field of soft robotics. The workshop will also serve to highlight important challenges still facing the field and potential approaches needed to overcome them.

ORGANISERS

   Steering Committee
- **Prof. Cecilia Laschi** – The BioRobotics Institute, Scuola Universitaria Superiore Pisa
- **Prof. Koh Hosoda** – Department of System Innovation, Osaka University
- **Dr. Wei Jun** – Additive Manufacturing Programme Manager, Singapore Institute of Manufacturing Technology, A*STAR
   Program Committee
- **Asst. Prof. Pablo Valdivia y Alvarado** – Engineering Product Development Pillar, Singapore University of Technology and Design (SUTD)
- **Lecturer Surya G. Nurzaman** – Mechanical Engineering Discipline, School of Engineering, Sunway Campus Monash University
- **Univ. Lect. Fumiya Iida** – Department of Engineering, University of Cambridge

Website: http://brd.sutd.edu.sg/icra2017softrobotics/

Workshop on Autonomous Structural Monitoring and Maintenance using Aerial Robots

Aerial robotics are rapidly integrated into a wide variety of important applications. But for these systems to be able to present their full potential, they should be able to act as something much more than a position-controlled camera in the sky. Recent breakthroughs in the fields of multi-modal perception, path planning for inspection and exploration, aerial manipulation design and control, as well as multi-robot collaboration bring us closer to the goal of autonomous structural monitoring and maintenance using aerial robots. As acknowledged from both the academic and the industrial sector, such a capability has tremendous potential in critical applications such as industrial infrastructure and industrial plant inspection and maintenance, monitoring of critical facilities (e.g. nuclear), nature conservation and security tasks. This workshop aims to bring together the different research communities, discuss recent results and strategize the next steps towards accomplishing full autonomy for structural inspection and aerial manipulation-based maintenance work-task execution. A rich schedule consisting of presentations from renowned leaders in the field, lighting talks from authors of submitted papers, a poster-session, a

demonstration of a comprehensive open source simulator environment to accelerate research, as well as a relevant round table discussion are planned.

ORGANIZERS

- **Markus Achtelik**
  Ascending Technologies – Intel Corporation, Konrad-Zuse-Bogen 4, 82152 Krailling, Germany
  Markus.Achtelik@asctec.de, http://www.asctec.de/
- **Kostas Alexis**
  Assistant Professor at University of Nevada, Reno, United States
  kalexis@unr.edu, www.kostasalexis.com
- **Gianluca Antonelli**
  Associate Professor at Università degli Studi di Cassino, Italy
  antontelli@unicas.it, http://www.eng.docente.unicas.it/gianluca_antonelli
- **Margarita Chli**
  Assistant Professor at ETH Zurich, Switzerland
  chlim@ethz.ch , http://margaritachli.com/
- **Anibal Ollero**
  Professor at the Universidad de Sevilla and Scientific Advisor of FADA-CATEC, Co-Chair of the IEEE RAS TC 1 Aerial Robotics and Unmanned Aerial Vehicles, Coordinator of the Aerial Robotics Topic Group of euRobotics, AEROARMS project
  Robotics, Vision and Control Group, Escuela Técnica Superior de ingeniería Camino de los Descubrimientos, 41092 Sevilla, Spain
  aollero@us.es, http://grvc.us.es/aollero Phone: +34 95 4487349
- **Roland Siegwart**
  Autonomous Systems Lab, ETH Zurich, Leonhardstrasse 21, LEE H 304, Zurich 8092, Switzerland
  rsiegwart@ethz.ch, http://www.asl.ethz.ch/
- **Kimon Valavanis**
  Professor & Chair, Department of Electrical & Computer Engineering, 2135 East Wesley Avenue, Denver, CO 80208,
  kimon.valavanis@du.edu, http://ritchieschool.du.edu/kimon-valavanis/

Website: http://www.aerial-monitoring-maintenance-workshop.com/

The Robotic Sense of Touch

ABSTRACT
This workshop focuses on the development of novel tactile sensors (i.e. the bodyware) and how they can contribute to robot intelligence (i.e. the mindware). Robots need touch to interact with the surroundings (humans and/or objects) safely and effectively, to learn about the outside world and to develop self-awareness. To achieve these goals, the artificial skin of the next generation should measure temperature, vibration, proximity and the complete force vectors on multiple contact points; also, it should be both soft and robust to facilitate long-term interactions. Still, major challenges are posed by the need to analyze and interpret massive amounts of data in a fast and accurate way, and to combine such sensing information with other cognitive and perceptual processes to achieve real understanding. While advanced computational techniques (e.g. deep learning, Bayesian inference) can critically improve data representations, bio-inspired strategies for multimodal integration, prediction and reasoning seem to be necessary as well to revolutionize the robotic sense of touch. Therefore, the goal of this workshop is to discuss if and how the recent advancements in tactile technology and data analysis have been

accompanied by an increased understanding of the ways in which tactile perception can support robot autonomy and cognition.

ORGANIZERS

- **Sophon Somlor** (contact person)
  Department of Modern Mechanical Engineering, Waseda University
  3F Shinjuku Lamdax building
  2-4-12 Okubo, Shinjuku, Tokyo 162-0042, Japan
  +81-3-6233-7823
  sophon-at-sugano.mech.waseda.ac.jp
- **Alexander Schmitz**
  Department of Modern Mechanical Engineering, Waseda University
  3F Shinjuku Lamdax building
  2-4-12 Okubo, Shinjuku, Tokyo 162-0042, Japan
  +81-3-6233-7823
  schmitz-at-aoni.waseda.jp
- **Lorenzo Jamone**
  Lecturer in Robotics at ARQ – Advanced Robotics at Queen Mary
  School of Electronic Engineering and Computer Science
  The Queen Mary University of London (UK)
  Mile End Road
  London E1 4NS
  +44-20-7882-7825
  l.jamone-at-qmul.ac.uk
- **Lorenzo Natale**
  Istituto Italiano di Tecnologia
  via Morego 30, 16163 Genova, Italy
  +39-010-71781946
  lorenzo.natale-at-iit.it
- **Gordon Cheng**
  Institute for Cognitive Systems, Technical University of Munich
  Karlstrasse 45/II, 80333 Munich, Germany
  +49 (89) 289-26800
  gordon-at-tum.de

Website: https://roboticsenseoftouchws.wordpress.com/

Recent Advances in Dynamics for Industrial Applications

ABSTRACT
The benefits of using dynamic models in the trajectory generation, planning, and control of industrial robots is a widely accepted notion within the robotics research community. Even if the models are not completely accurate, when available they can still be used to advantage, and offer superior performance over non-model-based methods. Yet with only a few exceptions, such dynamic model-based methods are not widely used in today's industrial robots. Why? Are there computational or other fundamental limits that prevent their effectiveness, or are purely kinematics-based methods sufficient for today's industrial robot applications?
This workshop aims to explore these and other related questions, and to shed light on the gap between the state-of-the-art on dynamics-based methods for robot planning and control and the needs of the practitioner.

ORGANIZERS

- **Jia Pan**, The City University of Hong Kong
- **Yuanqing Wu**, University of Bologna, Italy
- **Frank C. Park**, Seoul National University

Website: https://sites.google.com/view/icra2017dynamicsworkshop

Workshop on AI Planning and Robotics: Challenges and Methods

This workshop aims to bring together AI Planning & Scheduling and robotics researchers to share research and development progress in the area of robot planning and scheduling as well as discuss future directions and open challenges that the combined community should address. This initiative follows similar workshops, started in 2013 within the ICAPS Conference with the PlanRob WS series (http://pst.istc.cnr.it/planrob/), which established a sub-community of P&S and Robotics researchers interested and involved in robot planning. PlanRob approached community building from the P&S perspective. Our proposed workshop will now start building a bridge back to the robotics community. The robotics community's appetite for the application of AI techniques has already been demonstrated by the success of the ICRA'16 WS on AI for Long-Term Autonomy, which attracted over 100 attendees.
This workshop is envisaged as a full-day workshop consisting of invited talks, paper presentations, poster sessions, and a panel discussion. Several invited talks and a tutorial from experts in P&S and Robotics will provide the main structure of the day. Between invited talks, presentations of accepted papers will be scheduled. Moreover, authors of accepted papers will present their work during interactive poster sessions. The workshop will conclude with a panel discussion featuring the invited speakers.

ORGANIZERS

- **J. Christopher Beck**
  Department of Mechanical & Industrial Engineering
  University of Toronto, Canada.
- **Alberto Finzi**
  Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione
  University of Naples "Federico II", Naples, Italy
- **Nick Hawes**
  School of Computer Science
  University of Birmingham, Birmingham, United Kingdom.
- **Goldie Nejat**
  Department of Mechanical and Industrial Engineering
  University of Toronto, Canada.
- **AndreA Orlandini**
  Institute of Cognitive Science and Technology,
  National Research Council of Italy (CNR-ISTC), Rome, Italy.

Website: http://icra-ai-planrob17.istc.cnr.it/

Mechanics of Human Locomotion and the Development of Wearable Robotic Systems

ABSTRACT
Through developments in actuation, microelectronics, and control, there have been many advancements in robotics over the past decade. This has led to numerous promising applications, and often a closer, more intimate interaction between humans and machines. One of the most promising, yet most challenging applications of human-robot interaction is technologies that

assist with human locomotor performance, such as exoskeletons, and robotic prostheses. These systems have the potential to drastically improve quality of life, but there remains significant gaps in understanding that span robotics, machine learning, and biomechanics, among other fields. These interdisciplinary gaps in knowledge must be addressed before there will be seamless interaction between humans and wearable, assistive machines, that lead to lasting changes in human performance and clinical care.

The intent of this workshop is to foster collaboration and discussion regarding current work in the field, and the major technical barriers that must be addressed to reach our goal. We have assembled many of the leading speakers in the areas of biomechanics, wearable robotics, intent recognition, and control. The focus will be on wearable and assistive technologies for the lower extremities, including discussion of biomechanics and dynamics of gait. Specifically, we will

1. Assemble researchers working on relevant fields that are addressing challenges that lay ahead for achieving robust, biomechanically accurate, and effective wearable robots
2. Articulate the overarching challenges that must be addressed for safe and effective wearable robotic systems, with consideration to the short-term and long-term technical milestones that must be achieved

We expect researchers to engage in interdisciplinary discussions in different areas of human-machine interaction, rehabilitation, and robotics.

ORGANIZERS

- **Elliott Rouse**
  Assistant Professor, Northwestern University
  Director, Neurobionics Lab
- **Hyunglae Lee**
  Assistant Professor, Department of Mechanical and Aerospace Engineering
  Director, ASU Neuromuscular Control and Human Robotics Laboratory
- **Heike Vallery**
  Associate Professor, TU Delft
- **Panagiotis Artemiadis**
  Assistant Professor, Department of Mechanical and Aerospace Engineering
  Director, ASU HORC Lab

Website: http://icra2017.smpp.northwestern.edu/

Reproducible Research in Robotics: Current Status and Road Ahead

ABSTRACT

In Robotics research the replicability and reproducibility of results and their objective evaluation and comparison is very difficult to put into practice. Controlling for environmental considerations is hard, defining comparable metrics and identifying goal similarity across various domains is poorly understood, and techniques for . Even determining the information required to enable replication of results has been the subject of extensive discussion. Even worse, there is still no solid theoretical foundation for experimental replicability of experiments in robotics. This situation impairs both research progress and technology transfer. Significant progress has been made in these respects in recent years and this workshop will provide a curated view of the state of the art.

ORGANIZERS

- **F. Bonsignorio** (CORRESPONDING CONTACT PERSON)
  The BioRobotics Institute, SSSA
  Viale Rinaldo Piaggio 34,
  56025 Pontedera (Pisa), Italy

tel: +39 339 84 06 011
fabio.bonsignorio@santannapisa.it, fabio.bonsignorio@heronrobots.com,fabio.bonsignorio@gmail.com

- **Signe A. Redfield**
Naval Research Lab
4555 Overlook Ave, SW
Washington, D.C. 20375
signeredfield@gmail.com, signe@ieee.org
- **P. del Pobil**
Department of Engineering and Computer Science, Universitat Jaume I
12071 Castellon, Spain,
pobil@uji.es

Website: http://www.heronrobots.com/EuronGEMSig/gem-sig- -events/icra2017workshoprrr

Human Multi-Robot Systems Interaction

ABSTRACT
The objective of this workshop is to present the new developments in human multi-robot systems (MRS) interaction, which is an interdisciplinary research area across the robotics, controls, and human factors communities. We wish to identify the key challenges of MRS systems with human-in-the-loop, to explore the degree to which core elements of MRS research (e.g., distributed algorithms, decentralized planning, etc.) contribute to human-robot interaction (HRI), and to anticipate the future innovation in bringing human and MRS together. This workshop aims at promoting a discussion to identify and define the overarching ideas that can tie together different research direction in MRS and HRI, and lead to the definition of common practices and standards.

A constantly increasing community of researchers has been putting great effort in human-robot interaction (HRI). More recently, the interest in human multi-robot systems (MRS) interaction is motivated by the benefit of synergizing human intelligence with a team of cooperating robots to improve the joint human-robot system performance and reduce manpower and workload.

Researchers interested in HRI and MRS represent an inherently diverse community, since several competences are needed in this field, ranging from control systems to human factors, which include control, mechanical design, estimation, perception, planning, interaction, ergonomics, and psychology, just to list a few. While this fact could represent an incredible richness for human multi-robot systems interaction, perhaps instead it hinders the internal dialogue among researchers across different disciplinary and thus represents an obstacle for the constitution and development of a united field of research like other fields in robotics.

The main objective of this workshop is therefore to present the new cross-disciplinary developments in human multi-robot systems (MRS) interaction. We seek to identify the key challenges, framework, core elements of MRS systems with human-in-the-loop.

Toward this aim we will host a selection of invited keynote speakers that cover many different spirits among the HRI and multi-robot communities. We will ask them to give a historical perspective on their research, a current state-of-the-art, and insights on future trends and research challenges. The workshop will be organized in multiple sessions, each of which will be focused on a fundamental problem or aspect of human multi-robot systems interaction.

An interactive session will also be organized, in order to increase the number and the variety of the participants in the discussion, based on an open Call for Contributions.

The workshop will conclude with an open discussion among the participants, based on the main concepts drawn from the presentations.

ORGANIZERS

- **Yue Wang** (MAIN CONTACT)
  Department of Mechanical Engineering
  Clemson University
  Clemson, SC 29634, USA
  Phone: +1 (864) 656-5632
  E-mail: yue6@clemson.edu
  web: http://yue6.people.clemson.edu/
- **Antonio Franchi**
  Centre National de la Recherche Scientifique (CNRS)
  Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS)
  7, Avenue du Colonel Roche, 31077 Toulouse CEDEX 4, France
  Phone: +33 (0)56 133 6925
  E-mail: afranchi@laas.fr
  web: http://homepages.laas.fr/afranchi/
- **Nora Ayanian**
  Department of Computer Science
  University of Southern California
  3710 McClintock Ave, RTH 505
  Los Angeles, CA 90089-0781, USA
  Phone: +1 (213) 740-5377
  E-mail: ayanian@usc.edu
  web: http://www-bcf.usc.edu/~ayanian/
- **Lorenzo Sabattini**
  Department of Sciences and Methods for Engineering (DISMI), University of
  Modena and Reggio Emilia
  via Amendola 2 (Morselli building), 42122 Reggio Emilia, Italy
  Phone: +39 0522 522666
  E-mail: lorenzo.sabattini@unimore.it
  web: http://www.arscontrol.org/lorenzo-sabattini
- **Robert Fitch**
  Australian Centre for Field Robotics
  J04 – Rose Street Building
  The University of Sydney, Australia
  Email: rfitch@acfr.usyd.edu.au
  web: http://sydney.edu.au/engineering/people/robert.fitch.php

Website: https://cecas.clemson.edu/~yue6/

Biohybrid Machine by Small-scale Robotics and Systems

ABSTRACT
This workshop provides an opportunity to share and discuss with frontier researches on small-scale robotics and systems for developing the "Biohybrid Machine". This innovative research field is important to create excellent machines for various academic and industrial applications. Micro-nanorobotics is a key technology on the manipulation, assembly and control in small scale. The "Biohybrid Machine" are able to promote more innovations on optimal designs, high energy efficient, low energy consumption, high integration, and self-repairing by small-scale robotics and systems.
Small-scale robotics and systems are widely developed based on integration techniques of each miniaturized devices. Recent progresses in technologies on small-scale robotics and systems is readily applied to make hybridization between mechanical and biological components. In nature, various creatures are consisted of small-scale components and their design are important to obtain their excellent capabilities in mobility, robustness, efficiency, recuperation, communication and so on. Basically, those organisms are composed of small-scale systems in

multi-scale naturally as shown in the following figure. "Biohybrid Machine" is recently investigated to combine by mimicking biological structures with biomaterials and artificial materials based on small-scale robotics and systems. The "Biohybrid Machine" makes innovations extremely to promote for obtaining excellent capabilities in machines as next-generation engineering.

ORGANIZERS

- **M. Nakajima,**
- **K. Morishima,**
- **H. Sato,**
- **T. Fukuda,**
- **M. Sitti,**
- **S. Bergbreiter,**
- **L. Ricotti**

Website: https://biohybridmachineicra17.wordpress.com/

Learning and control for autonomous manipulation systems: the role of dimensionality reduction

ABSTRACT
New generation of robots, to serve and substitute humans in various kinds of application, should have comparable abilities to deftly move, autonomously learn and make decisions. Analytical approaches to manipulation require precise model of the objects, accurate description of the task, and evaluation of object affordance, which all make the process time consuming. To learn and execute new tasks just as humans do, i.e. through trial-and-error and compliant adaptation to the environment, human-like physical interaction is crucial. Therefore, advanced mechanical designs such as tendon-driven actuation, underactuated compliant mechanisms and hyper-redundant/continuum robots might exhibit enhanced capabilities of adapting to changing environments. As a matter of fact, high degrees of freedom (DoF) and compliance increase the complexity of modelling and control of these devices. To this purpose, the adoption of coordinated motion patterns leads to a problem of reduced dimension. As a consequence, model-based control strategies of manipulation activities can be learned from human experience and, relying on dimensionality reduction, can be integrated with model-free reinforcement learning algorithms which have the potential to learn from actions.
The purpose of the workshop is to portray the level of autonomy that anthropomorphic robotic systems have reached today and to chart possible paths towards improved manipulation capabilities by means of self-adaptability to the environment. The workshop intends to spotlight how autonomy depends on the ability to adapt to the environment by learning from experience, and how, for this purpose, physical interaction is critical and consequently smart design makes the difference. This workshop aims at discussing the integration of learning, control and design aspects that should not be separated in the complex problem of robotic manipulation. Indeed, these aspects can interact and take advantage of one another being inspired by the functioning, reasoning and physical resemblance of human beings. Of course, in this contest the perception is involved in the process and the integration of visual and tactile sensing is a crucial issue during the interaction with the environment.

ORGANIZERS

- **Dr. Fanny Ficuciello (CONTACT PERSON)**
  PRISMA Lab
  Department of Electrical Engineering and Information Technology

University of Naples Federico II
via Claudio 21, 80125, Naples, Italy
phone: +39 081 7683916
fanny.ficuciello@unina.it
http://wpage.unina.it/fanny.ficuciello

- **Dr. Sylvain Calinon**
  Idiap Research Institute
  Centre du Parc
  Rue Marconi 19, PO Box 592, CH-1920 Martigny, Switzerland
  phone: +41 27 721 77 61
  sylvain.calinon@idiap.ch
  http://calinon.ch/

- **Dr. Pietro Falco**
  Marie Curie Fellow
  Technische Universität München
  Department of Dynamic Human-Robot-Interaction for Automation Systems
  Karlstraße 45, 5. OG. 80333 München,
  phone: +49(89) 289-26885
  pietro.falco@tum.de
  https://www.hri.ei.tum.de/en/team/pietro-falco/

Website: http://www.icra2017-ws-lecom.unina.it/

Disaster Response Robots: Design Principles and Control for Effective Mobility and Manipulation

ABSTRACT
In the past years several natural or man-made disasters such as earthquakes and tsunami, or accidents in nuclear power plants have dramatically highlighted the need for effective and efficient robotic systems that can be deployed rapidly after the disaster, to assist in tasks too hazardous for humans to perform. Unfortunately, despite the remarkable efforts and developments in robotics today's state of the art disaster response robots still does not demonstrate adequate readiness and performance to help addressing this need in realistic disaster conditions. To operate within infrastructures originally designed for humans, but which have become hostile or dangerous, a robot should possess a rich repertoire of human-like skills. It should also exhibit the physical body power, agility and robustness, the manipulation and locomotion capability, and ultimately the effective ability to reach places and physically interact with a harsh environment. This workshop targets to cover the recent advancements in disaster response robotics particularly in the area of robot design principles and control for effective locomotion and manipulation.

ORGANIZERS

- **Nikos Tsagarakis (contact person)**
  Department of Advanced Robotics, Instituto Italiano di Tecnologia, Via Morego 30
  16163, Genova, Italy
  Tel: +39-010-71781-428
  Email: nikos.tsagarakis@iit.it
  URL: https://www.iit.it/it/people/nikos-tsagarakis
- **Petter Ögren**

Centre for Autonomous Systems (CAS), Kungliga Tekniska Högskolan (KTH),
Teknikringen 14, plan 6, SE – 100 44 Stockholm, SWEDEN
Tel: +46 (0) 8 790 6646
Email: petter@kth.se
URL: http://www.csc.kth.se/~petter/

- **Patric Jensfelt**
  Centre for Autonomous Systems (CAS), Kungliga Tekniska Högskolan (KTH),
  Teknikringen 14, plan6,7
  Tel: +46 8 790 67 31
  Email: patric@kth.se
  URL: https://www.kth.se/profile/patric/
- **Sven Behnke**
  Universitry of Bonn,Computer Science Institute
  Friedrich-Ebert-Allee 144, 53113 Bonn
  Tel: +49 (0) 228 73-4116
  Email: behnke@cs.uni-bonn.de
  URL: http://www.ais.uni-bonn.de/behnke/

Website: https://icra2017wsdisaster.wordpress.com/

Assistive Robotics: From the Natural to the Artificial and Back Again

ABSTRACT
The objective of this workshop is to explore how robotics technology can drive the restoration of function in people with movement disabilities. To achieve this objective the workshop is organized around four related areas: 1) treatment of neuromuscular conditions that cause movement disabilities, 2) human motor control, 3) human-like control of robots, and 4) robotic assistive technologies. Treatment of neuromuscular conditions is ultimately the goal of many assistive robotic technologies. The field of human motor control can help roboticists understand what natural human movement is and how it is controlled. Leveraging human motor control research has led to more natural and complex behaviors by artificial robots. The organizers envision assistive robotics that naturally interact with human systems. The workshop is designed to broadly define the state of the art in each of the four areas, allow experts in the four areas to have an open discussion, allow speakers to contribute talks on specific research in the four areas, bring together senior and junior researchers across the four areas for meaningful discussion, and define new research directions and opportunities for collaboration.

ORGANIZERS

- **Arash Ajoudani**
- **Kyujin Cho**
- **Tamar Flash**
- **Eric Schearer**

Website: http://hri.iit.it/icra-workshop-2017

Workshop on Innovative Haptic Interfaces emerging from Soft Robotics

ABSTRACT
The field of soft robotics has made inroads into a number of applications that have previously been dominated by rigid robots such as assistive technologies, surgical robotics and haptics. This workshop aims to bring together experts active in the field of creating sensors interacting

with soft objects, understanding how sensory information is fed back to the human and studying haptic devices made of soft materials. We will explore the synergies that will arise from bringing together soft robotics and haptics and identify the advantages that these new soft materials bring to the field of haptics.

This ICRA 2017 workshop will provide a review of current technology using silicone and rubber materials for creating sensors on the one hand and haptic devices on the other hand. This will help exploring the reasons of current emergence of soft haptic interfaces and identifying the benefits associated with applying soft robotics in this field. The workshop will explore the challenges that lie ahead to create new robot systems that can enhance feeding back haptic information to the human in the future.

Round table discussions will focus on obstacles and challenges and the future direction. As part of the workshop, real demonstrators will be presented.

ORGANIZERS

- **Dr Helge Wurdemann**
  Department of Mechanical Engineering, University College London, UK
  Email: h.wurdemann@ucl.ac.uk
- **Prof. Shervanthi Homer-Vanniasinkam**
  Warwick Medical School, University of Warwick, Coventry, UK
  Leeds Vascular Institute & Leeds Institute of Genetics, University of Leeds, UK
  Department of Mechanical Engineering, University College London, UK
- **Prof. Kaspar Althoefer**
  School of Engineering and Materials Science
  Queen Mary University of London, UK
- **Prof. Cecilia Laschi**
  The BioRobotics Institute
  Scuola Superiore Sant'Anna, Pisa, Italy
- **Prof. Allison M. Okamura**
  Mechanical Engineering Department
  Stanford University, USA
- **Prof. Mandayam Srinivasan**
  Department of Computer Science
  University College London, UK
- **Dr Vijay Pawar**
  Department of Computer Science
  University College London, UK
- **Prof. Yuru Zhang**
  Robotics Institute, Department of Mechanical Engineering
  Beihang University, Beijing, China
- **Prof. Dangxiao**
  Robotics Institute, Department of Mechanical Engineering
  Beihang University, Beijing, China

Website: http://icra2017.softhaptics.website/

Workshop on Multi-robot Perception-Driven Control and Planning

ABSTRACT
The development of cheap, versatile robots has prompted an intense research in the past decade in multi-robot systems and their applications. Almost any robotic task can benefit from the cooperation of several robots, working together towards a common goal. On the other hand, the coordination of a team of robots has raised numerous questions and research problems

involving perception, planning and control. One of the main challenges in these systems is to maintain optimality in the control actions and the navigation plans for the whole team when each robot only has partial information due to local sensing and limited communications.

The aim of this workshop is to discuss ideas to overcome these challenges, analyze the state of the art in perception-based solutions for planning and control of multi-robot systems and identify the most promising research directions in the context of cooperative perception and navigation. To achieve these goals, we will bring together leading researchers from related areas to discuss the latest theoretical and algorithmic solutions where the limitations of local perception and bandwidth represent the centerpiece component of the problem.

ORGANIZERS

- **Javier Alonso-Mora,** Delft University of Technology
- **Eduardo Montijano,** Universidad de Zaragoza
- **Daniela Rus**, MIT
- **Mac Schwager,** Stanford University
-

Website: http://webdiis.unizar.es/~edumonti/17_ICRA_WS/

Workshop on Event-based Vision

ABSTRACT

This workshop is dedicated to event-based vision sensors and algorithms. Event-based cameras are revolutionary vision sensors with three key advantages: a measurement rate that is almost 1 million times faster than standard cameras, a latency of microseconds, and a high dynamic range that is six orders of magnitude larger than that of standard cameras. Event-based sensors open frontiers which are unthinkable with standard cameras (which have been the main sensing technology of the past 50 years). These revolutionary sensors enable the design of a new class of algorithms to track a baseball in the moonlight, build a flying robot with the same agility of a fly, localizing and mapping in challenging lighting conditions and at remarkable speeds. These sensors became commercially available in 2008 and are slowly being adopted in mobile robotics. They covered the main news in 2016 with Intel and Bosch announcing a $15 million investment in event-camera company Chronocam and Samsung announcing its use with the IBM's brain-inspired TrueNorth processor to recognize human gestures. This workshop will cover the sensing hardware as well as the processing, learning, and control methods needed to take advantage of these sensors.

ORGANIZERS

- **Davide Scaramuzza** - University of Zurich
- **Guillermo Gallego** - University of Zurich
- **Andrea Censi** - MIT / ETH Zurich / nuTonomy

Website: http://rpg.ifi.uzh.ch/ICRA17_event_vision_workshop.html

AI in Automation

ABSTRACT

A new wave in Artificial Intelligence based on Deep Learning enabled by massive datasets, GPUs, and cloud computing is being embraced by industry for applications from autonomous driving to digital personal assistants. What are AI's implications for Factory Automation, where labor costs are increasing, product lifecycles are getting shorter, and customized products are more popular?

This workshop will explore the latest advances with experts from academia and industry, including national project updates from Japan and China. One area of interest is advances in Deep Learning for Machine Vision with applications in inspection. Another is Deep Learning from Demonstrations, where robots learn from observations of humans performing tasks such as assembly and warehouse order fulfilment.

ORGANIZERS

- **Kensuke Harada** - Osaka University/AIST, Japan
- **Dinesh Manocha** - UNC Chapel Hill, USA
- **Ken Goldberg** - University of California, Berkley, USA

Website: https://ai-automation.jimdo.com/

C4 Surgical Robots: Compliant, Continuum, Cognitive, and Collaborative

ABSTARCT
New robotic technologies have led to significant advances in surgery in recent decades. Motivated to further reduce the invasiveness of robot-assisted surgery, new robotic systems are being created that enter the patient's body via single ports or natural orifices and can reach and operate in difficult-to-access sites. However, there are still challenges to implement minimally invasive surgery with these new surgical robotic systems, such as the design, control, and sensing of surgical robots for specific clinical applications. In this workshop we will focus on new surgical robots that are compliant, continuum, cognitive, and collaborative (C4 surgical robots). Integrating the emerging technologies in soft robotics, smart materials, co-robotics, and artificial intelligence has the potential to enable new C4 surgical robots. This workshop will bring together world-class researchers to present state-of-the-art research results in surgical robotics and the potential challenges for creating and implementing C4 robots for clinical applications.

ORGANIZERES

- **Hongliang Ren** ren@nus.edu.sg &**Jing Guo** (bieguoj@nus.edu.sg) National University of Singapore
- **Christos Bergeles** Department of Medical Physics and Biomedical Engineering,University College London
- **Pierre E. Dupont** Boston Children's Hospital, Harvard Medical School pierre.dupont@childrens.harvard.edu
- **Philippe Poignet**, LIRMM, CNRS-University of Montpellier, 161 rue Ada, Montpellier, 34095, France.poignet@lirmm.fr
- **Michael Yip**, ECE Department, University of California at San Diego Email:yip@ucsd.edu
- **Ron Alterovitz**, Department of Computer Science, University of North Carolina at Chapel Hill, E-mail:ron@cs.unc.edu
- **Chao Liu**, CNRS; LIRMM, CNRS-University of Montpellier, 161 rue Ada, Montpellier, 34095, France. Email: liu@lirmm.fr

- **Animesh Garg**, Department of Computer Science Stanford University, Stanford, CA USA 94305, Email:<u>garg@cs.stanford.edu</u>

Website: <u>http://bioeng.nus.edu.sg/mm/c4r.html</u>

Robotics and Vehicular Technologies for Self-driving cars

ABSTRACT
The rising trend of self-driving cars has pushed the envelop for the state of the art vehicular technologies and has evolved several day to day applications. This evolution required better sensing hardware, robust planning algorithms and the best control methods. At this juncture, the robotics community has identified and addressed most of the pressing issues to develop the foundation of self-driving cars. As we advance this field to build higher levels of applications such as intelligent and cooperative networks, we need a complete understanding of its fundamentals. Therefore, the goal of this workshop is to discuss and learn about the state of the art of self-driving car technologies from academic, industrial and government experts and be prepared to move together as a community to the next level of autonomous intelligent world!

ORGANIZERS

- **Marcelo Ang**, NUS
- **David Hsu**, NUS
- **Christian Laugier**, INRIA
- **Malika Meghjani**, SMART
- **Daniela Rus**, MIT

Website: <u>http://cim.mcgill.ca/~malika/ICRA17_WS/</u>

IC^3 - Industry of the future: Collaborative, Connected, Cognitive Novel approaches stemming from Factory of the Future & Industry 4.0 initiatives

ABSTRACT
Manufacturing processes are being extensively transformed and actions such as the Industry 4.0 and Factory of the Future are being launched to drive this change. Indeed, industrial processes are moving fast towards the so-called cyber-physical systems, smart productive environments where humans, machines, the environment and the Internet of Things mutually complement safely and efficiently. The impact of ICTs on manufacturing is leading to an evolution of standards and models, where flexibility and adaptability are crucial for innovation and competitiveness.
The Industry of the future will be Collaborative, Connected and Cognitive (IC^3). This IC^3 paradigm could herald a fundamental positive impact on global economy, with both automation and artificial intelligence (AI) driving the fourth industrial revolution. Furthermore, the emergence of Circular Economy opens up new opportunities for robotics and automation to deliver new and efficient solutions for high quality disassembly and dismantling tasks, leading to yet unexplored paradigms of sustainable industry. We already have an Industry 4.0 framework, a Robotics and Autonomous Systems substratum and an AI added value. These building blocks shall play an ensemble to produce ground-breaking, joined-up solutions. This workshop will trace the current trends in manufacturing with the expected impact of promoting safety at work, increasing efficiency and competitiveness, and improving the eco-sustainability of industrial processes.

ORGANIZERS
       ACADEMIA
- **Paolo Dario** Scuola Superiore Sant'Anna (SSSA)
  Professor of Biomedical Robotics,
  Director of The BioRobotics Institute of Scuola Superiore Sant'Anna, Pisa, Italy,
  IEEE Fellow, IEEE RAS Past President
- **Alois Knoll** Technische Universität München
  Professor of Computer Science,
  Head of the Robotics and Embedded Systems Group,
  IEEE Senior Member
- **Lakmal Seneviratne** Robotics Institute Khalifa University Robotics Institute,
  Khalifa University, Abu Dhabi, UAE
  Professor of Mechanical Engineering,
  Associate Vice President for Research,
  Director of the Khalifa University Robotics Institute (KURI)
         INDUSTRY
- **Massimo Maffei Piaggio & C. S.p.A.**
  Vice President Manufacturing Technologies and Infrastructure-Facilities
  Manufacturing Technologies, Piaggio & C. S.p.A.
- **Arturo Baroncelli Comau S.p.A.**
  COMAU Robotics Business Development Manager, Past President and present
  member of the Board of the International Federation of Robotics (IFR), Member of
  the euRobotics AISBL Board of Directors

Website: http://sssa.bioroboticsinstitute.it/workshops/IC3_icra2017

Tutorials

Tutorial on AI Planning for Robotics

ABSTRACT
The main goal of this tutorial is to show how state-of-the-art formalisms in planning and scheduling (P&S) are used to model robotics domains; some of the challenges and solutions involved in dispatching plans on-board robotic platforms; and to provide an overview of the ROSPlan framework. By so doing, we hope to encourage the rapid development of P&S techniques for robotics. Moreover, the tutorial aims to use the ICRA forum as a means to discuss the main challenges related to planning for autonomous robots (deliberative, reactive, continuous planning and execution etc.).

Tutorial Content
Part 1: AI Planning for Long-Term Autonomy
AI planning for long-term autonomy means an autonomous agent planning for unsupervised periods of days or months. Many interesting robotics problems are problems for long-term autonomy. For example, in service environments, or seabed inspection and maintenance. Planning for these scenarios requires rich models to capture the uncertain and evolving environment, and robust methods of execution. There are many open problems, including the handling of temporal constraints, how to exploit opportunities, and how to handle failure and anticipate it in the future.

This part provides an overview of planning for long-term autonomy. We focus on modelling and solving P&S problems for robotics systems, including some examples of P&S solutions taken from different teams working on various domains.

Part 2: Integrating AI Planning in ROS

The second part of the tutorial will focus on integrating AI Planning and Scheduling into a ROS system, and cover the challenges that arise in plan execution, such as dealing with incomplete knowledge, state estimation, error detection and recovery, and long-term learning. This will cover some case studies in ROSPlan (using mobile bases, AUVs, quadcopters).

Part 3: Open discussion on AI Planning for Robot Control

The final part of the tutorial will discuss open issues and new opportunities. We will report on the recent news from the Dagstuhl Workshop on Planning and Robotics, held on January 10-15, 2017.

ORGANIZERS

- **Michael Cashmore**
  Website: http://www.inf.kcl.ac.uk/staff/cashmore/
  Email: michael.cashmore at kcl.ac.uk
- **Daniele Magazzeni**
  Website: http://www.inf.kcl.ac.uk/staff/danmag/
  Email: daniele.magazzeni at kcl.ac.uk

Website: http://kcl-planning.github.io/ROSPlan/tutorials/tutorialICRA2017

Buzz Tutorial

ABSTRACT

Swarm robotics is a discipline that studies fully decentralized approaches for the coordination of large-scale teams of robots (*swarms*). Research in this field is ambitious: robot swarms are envisioned for scenarios for which solutions are today impractical, too dangerous, or inexistent. From drones to self-driving cars, robot swarms will become pervasive thanks to the development of the Internet-of-Things, and will be used in many applications. Examples of such applications are search and rescue operations, industrial and agricultural inspection, coordinated vehicle platooning, space exploration, and medical or surgical activities. We envision a world where a designer can specify the behaviour of heterogeneous groups of robots, and package this behaviour in an application that can be installed on multiple robotic systems. Swarm-based solutions will likely form the backbone for the upcoming self-driving car infrastructure, and will act as an enabling technology to make widespread robotics a reality.

While it seems natural to deal with robot swarms as yet another instance of a classical distributed system, important aspects set the former apart from the latter. The dynamics of robot swarms are characterized by an inseparable mixture of spatial and network aspects. Spatial aspects include the fact that robots move, and modify their surrounding environment, while network aspects include a communication modality based on range-limited, gossip-based message passing, and an ever changing topology due to robot navigation across the environment. As a result, the mapping between swarm-level requirements and individual actions is a problem whose solution exceeds current approaches to distributed system design. Designing and developing swarm behaviors is achieved today through a slow trial-and-error process, in which the expertise of the designer and his or her ability to encode complex behaviors are the main factors for success.

In this tutorial we present Buzz, a programming language designed to provide an adequate level of abstraction to allow developers to express complex swarm algorithms comfortably. Two opposite approaches have been proposed in swarm robotics:
- The *bottom-up* approach, in which the focus is on individual robots and their low-level interactions; and

- The *top-down* approach, in which a swarm is treated as an continuous, unique entity (e.g., aggregate programming or spatial computing).

While the bottom-up approach ensures total control on the design, the amount of detail exposed to the developer is often overwhelming. In contrast, the top-down approach presents a simple abstraction of the swarm, but it prevents the developer from fine-tuning the behavior of individual robots.

Buzz is based on the idea that the developer should be offered **both** levels of abstraction, and that the syntax of the language should allow for seamless mixing of bottom-up and top-down constructs. Buzz includes a number of constructs specifically designed for top-down swarm-level development, such as primitives for group formation and management, local communication, and global consensus. Buzz was designed to work with small systems (for the Internet-of-Things), and its virtual machine can fit in less than 12kB of memory.

ORGANIZERS

- Giovanni Beltrame
- Carlo Pinciroli

Website: http://the.swarming.buzz/ICRA2017/

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May 29 - June 3, 2017, Marina Bay Sands Convention Centre, Singapore

Program at a Glance

ICRA 2017 Technical Program Monday May 29, 2017											
Half-Day Tutorial 1	Full-Day Workshop 2	Full-Day Workshop 3	Full-Day Workshop 4	Full-Day Workshop 5	Full-Day Workshop 6	Full-Day Workshop 7	Full-Day Workshop 8	Full-Day Workshop 9	Full-Day Workshop 10	Full-Day Workshop 11	Full-Day Workshop 12
08:30-12:00 Rm. 4011 Tutorial MoTA1 *Tutorial on AI Planning for Robotics* 13:30-17:00 Rm. 4011 Tutorial MoT1 *Buzz: A Programming Language for Multi-Robot Systems*	08:30-17:00 Rm. 4111 Full-Day Workshop MoW2 *Advances and Challenges on the Development, Testing and Assessment of Assistive and Rehabilitation Robots: Experiences from Engineering and Human Science Research*	08:30-17:00 Rm. 4311/4312 Full-Day Workshop MoW3 *Robust Perception, Planning, and Control for Legged Robot Locomotion in Challenging Domains*	08:30-17:00 Rm. 4411/4412 Full-Day Workshop MoW4 *Sensor-Based Object Manipulation for Collaborative Assembly*	08:30-17:00 Rm. 4511/4512 Full-Day Workshop MoW5 *Warehouse Picking Automation Workshop 2017: Solutions, Experience, Learnings and Outlook of the Amazon Picking Challenge*	08:30-17:00 Rm. 4611/4612 Full-Day Workshop MoW6 *Advanced Fabrication and Morphological Computation for Soft Robotics*	08:30-17:00 Rm. 4711/4712 Full-Day Workshop MoW7 *Autonomous Structural Monitoring and Maintenance Using Aerial Robots*	08:30-17:00 Rm. 4613/4713 Full-Day Workshop MoW8 *The Robotic Sense of Touch: From Sensing to Understanding*	08:30-17:00 Rm. 4811/4812 Full-Day Workshop MoW9 *Recent Advances in Dynamics for Industrial Applications*	08:30-17:00 Rm. 4911/4912 Full-Day Workshop MoW10 *AI Planning & Robotics: Challenges and Methods*	08:30-17:00 Rm. 4813/4913 Full-Day Workshop MoW11 *Mechanics of Human Locomotion and the Development of Wearable Robotic Systems*	08:30-17:00 Rm. 4211/4212 Full-Day Workshop MoW12 *Reproducible Research in Robotics: Current Status and Road Ahead*
18:30-21:00 Flower Dome Hall, Gardens-by-the Bay **Welcome Reception**											

	ICRA 2017 Technical Program Tuesday May 30, 2017												
Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7	Track 8	Track 9	Track 10	Track 11	Track 12	Forum 1	Forum 2
08:00-08:45 Grand ballroom *Opening Ceremony*													
08:45-09:45 Grand ballroom Plenary 1 *Modeling the Possibilities: From the Chalkboard to the Race Track to the World Beyond - J Christian Gerdes (Stanford University, USA)*													
09:55-11:10 Rm. 4011 Regular Session TUA1 *Actuators 1*	09:55-11:10 Rm. 4111 Regular Session TUA2 *Optimization and Optimal Control*	09:55-11:10 Rm. 4311/4312 Regular Session TUA3 *Computer Vision 1*	09:55-11:10 Rm. 4411/4412 Regular Session TUA4 *ITS Perception & Planning*	09:55-11:10 Rm. 4511/4512 Regular Session TUA5 *Multi-Robot Systems 1*	09:55-11:10 Rm. 4611/4612 Regular Session TUA6 *Learning and Adaptive Systems 1*	09:55-11:10 Rm. 4711/4712 Regular Session TUA7 *Force and Tactile Sensing 1*	09:55-11:10 Rm. 4613/4713 Regular Session TUA8 *Haptics and Haptic Interfaces*	09:55-11:10 Rm. 4811/4812 Regular Session TUA9 *TRO Session - Perception and Planning*	09:55-11:10 Rm. 4911/4912 Regular Session TUA10 *Rehabilitation Robotics*	09:55-11:10 Rm. 4813/4913 Regular Session TUA11 *Intelligent and Flexible Automation*	09:55-11:10 Rm. 4211/4212 Invited Presentation TUA12 *Special Session - Intelligent Manufacturing and Automation*	09:55-11:10 Sands N Forum TUA13 *Industry Forum 1*	09:55-11:10 Sands O Forum TUA14 *Innovation & Entrepreneur-Ship Forum 1*
11:10-11:30 *Coffee_Break*													
11:30-12:45 Rm. 4011 Regular Session TUB1 *Actuators 2*	11:30-12:45 Rm. 4111 Regular Session TUB2 *Motion Planning and Optimization*	11:30-12:45 Rm. 4311/4312 Regular Session TUB3 *Computer Vision 2*	11:30-12:45 Rm. 4411/4412 Regular Session TUB4 *Autonomous Agent*	11:30-12:45 Rm. 4511/4512 Regular Session TUB5 *Multi-Robot Systems 2*	11:30-12:45 Rm. 4611/4612 Regular Session TUB6 *Learning and Adaptive Systems 2*	11:30-12:45 Rm. 4711/4712 Regular Session TUB7 *Force and Tactile Sensing 2*	11:30-12:45 Rm. 4613/4713 Regular Session TUB8 *Human-Robot Interaction 1*	11:30-12:45 Rm. 4811/4812 Regular Session TUB9 *Multilegged Robots*	11:30-12:45 Rm. 4911/4912 Regular Session TUB10 *Medical Robots and Systems 1*	11:30-12:45 Rm. 4813/4913 Regular Session TUB11 *Design and Manufacturing*	11:30-12:45 Rm. 4211/4212 Invited Presentation TUB12 *Special Session - Medical and Micro Robotics*	11:30-12:45 Sands N Forum TUB13 *Industry Forum 2*	11:30-12:45 Sands O Forum TUB14 *Innovation & Entrepreneur-Ship Forum 2*

12:45-13:45 Lunch_Break

13:45-14:15 Grand ballroom Keynote 1 *EndoMaster: A Surgical Robot's Journey from the Research Lab to the Operating Theatre - Louis Phee (Nanyang Technological University, Singapore)*

14:15-14:45 Grand ballroom Keynote 2 *Capturing Vivid 3D Models of the World from Video - Lourdes Agapito (University College London, UK)*

14:45-16:00 Rm. 4011 Regular Session TUC1 *Actuators 3*	14:45-16:00 Rm. 4111 Regular Session TUC2 *Planning*	14:45-16:00 Rm. 4311/4312 Regular Session TUC3 *Computer Vision 3*	14:45-16:00 Rm. 4411/4412 Regular Session TUC4 *Autonomous Vehicle*	14:45-16:00 Rm. 4511/4512 Regular Session TUC5 *Distributed Robot Systems 1*	14:45-16:00 Rm. 4611/4612 Regular Session TUC6 *Learning and Adaptive Systems 3*	14:45-16:00 Rm. 4711/4712 Regular Session TUC7 *Grasping 1*	14:45-16:00 Rm. 4613/4713 Regular Session TUC8 *Human-Robot Interaction 2*	14:45-16:00 Rm. 4811/4812 Regular Session TUC9 *Best Conference Paper Award*	14:45-16:00 Rm. 4911/4912 Regular Session TUC10 *Medical Robots and Systems 2*	14:45-16:00 Rm. 4813/4913 Regular Session TUC11 *Industrial Robots*	14:45-16:00 Rm. 4211/4212 Invited Presentation TUC12 *Special Session - Human Centric Robotics*	14:45-16:00 Sands N Forum TUC13 *Industry Forum 3*	14:45-16:00 Sands O Forum TUC14 *Innovation & Entrepreneur-Ship Forum 3*

16:00-16:25 Coffee_Break

16:25-17:40 Rm. 4011 Regular Session TUD1 *Actuators 4*	16:25-17:40 Rm. 4111 Regular Session TUD2 *Collision Avoidance*	16:25-17:40 Rm. 4311/4312 Regular Session TUD3 *Computer Vision 4*	16:25-17:40 Rm. 4411/4412 Regular Session TUD4 *Visual-Based Navigation*	16:25-17:40 Rm. 4511/4512 Regular Session TUD5 *Distributed Robot Systems 2*	16:25-17:40 Rm. 4611/4612 Regular Session TUD6 *Learning and Adaptive Systems 4*	16:25-17:40 Rm. 4711/4712 Regular Session TUD7 *Grasping 2*	16:25-17:40 Rm. 4613/4713 Regular Session TUD8 *Human-Robot Interaction 3*	16:25-17:40 Rm. 4811/4812 Regular Session TUD9 *Best Student Paper Award*	16:25-17:40 Rm. 4911/4912 Regular Session TUD10 *Medical Robots and Systems 3*	16:25-17:40 Rm. 4813/4913 Regular Session TUD11 *Wheeled Robots*	16:25-17:40 Rm. 4211/4212 Invited Presentation TUD12 *Special Session - Advanced Robot Design*	16:25-17:40 Sands N Forum TUD13 *Industry Forum 4*	16:25-17:40 Sands O Forum TUD14 *Innovation & Entrepreneur-Ship Forum 4*

	Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7	Track 8	Track 9	Track 10	Track 11	Forum 1	Forum 2	Forum 3
ICRA 2017 Technical Program Wednesday May 31, 2017														
	08:20-09:20 Grand ballroom Plenary 2 *Nobel Turing Challenge: Grand Challenge of AI, Robotics, and Systems Biology - Hiroaki Kitano (Sony Research Lab, Japan)*													
	09:30-10:45 Rm. 4011 Regular Session WeA1 *Kinematics and Dynamics*	09:30-10:45 Rm. 4111 Regular Session WeA2 *Mapping 1*	09:30-10:45 Rm. 4311/4312 Regular Session WeA3 *Visual Learning*	09:30-10:45 Rm. 4411/4412 Regular Session WeA4 *Sensor and Robtoic Networks*	09:30-10:45 Rm. 4511/4512 Regular Session WeA5 *Aerial Robot 1*	09:30-10:45 Rm. 4611/4612 Regular Session WeA6 *Cognitive Robotics*	09:30-10:45 Rm. 4711/4712 Regular Session WeA7 *Grippers and Other End-Effectors*	09:30-10:45 Rm. 4613/4713 Regular Session WeA8 *Physical Human-Robot Interaction*	09:30-10:45 Rm. 4811/4812 Regular Session WeA9 *TRO Session - Actuation, Locomotion, Grasping*	09:30-10:45 Rm. 4911/4912 Regular Session WeA10 *Medical Robots and Systems 4*	09:30-10:45 Rm. 4813/4913 Regular Session WeA11 *Automation*	09:30-10:45 Rm. 4211/4212 Forum WeA12 *Government Forum 1*	09:30-10:45 Sands N Forum WeA13 *Industry Forum 5*	09:30-10:45 Sands O Forum WeA14 *Innovation & Entrepreneur-Ship Forum 5*
	10:45-11:05 *Coffee_Break*													
	11:05-12:20 Rm. 4011 Regular Session WeB1 *Compliance*	11:05-12:20 Rm. 4111 Regular Session WeB2 *Mapping 2*	11:05-12:20 Rm. 4311/4312 Regular Session WeB3 *Visual Localization*	11:05-12:20 Rm. 4411/4412 Regular Session WeB4 *Sensor Fusion and Control*	11:05-12:20 Rm. 4511/4512 Regular Session WeB5 *Aerial Robot 2*	11:05-12:20 Rm. 4611/4612 Regular Session WeB6 *Policy Search*	11:05-12:20 Rm. 4711/4712 Regular Session WeB7 *Robotic Manipulation*	11:05-12:20 Rm. 4613/4713 Regular Session WeB8 *Humanoid Robots 1*	11:05-12:20 Rm. 4811/4812 Regular Session WeB9 *Biologically-Inspired Robots 1*	11:05-12:20 Rm. 4911/4912 Regular Session WeB10 *Medical Robots and Systems 5*	11:05-12:20 Rm. 4813/4913 Regular Session WeB11 *Service Robotics 1*	11:05-12:20 Rm. 4211/4212 Forum WeB12 *Government Forum 2*	11:05-12:20 Sands N Forum WeB13 *Industry Forum 6*	11:05-12:20 Sands O Forum WeB14 *Innovation & Entrepreneur-Ship Forum 6*
	12:30-13:00 Grand ballroom Keynote 3 *Industry 4.0: Automation and Robotics - Peter Luh (University of Connecticut, US)*													
	13:00-13:30 Grand ballroom Keynote 4 *Research at the Intersection between Robots and Play: Designing Robots for Children's Healthcare - Ayanna Howard (Georgia Tech, USA)*													

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13:30-14:30 Lunch_Break											
14:30-15:45 Rm. 4011 Regular Session WeC1 *Tendon/Wire Robotics*	14:30-15:45 Rm. 4111 Regular Session WeC2 *Motion and Path Planning 1*	14:30-15:45 Rm. 4311/4312 Regular Session WeC3 *Visual Servoing*	14:30-15:45 Rm. 4411/4412 Regular Session WeC4 *Slam 1*	14:30-15:45 Rm. 4511/4512 Regular Session WeC5 *Aerial Robot 3*	14:30-15:45 Rm. 4611/4612 Regular Session WeC6 *RGB-D Perception*	14:30-15:45 Rm. 4711/4712 Regular Session WeC7 *Manipulation Planning 1*	14:30-15:45 Rm. 4613/4713 Regular Session WeC8 *Humanoid Robots 2*	14:30-15:45 Rm. 4811/4812 Regular Session WeC9 *Biologically-Inspired Robots 2*	14:30-15:45 Rm. 4911/4912 Regular Session WeC10 *Surgical Robotics 1*	14:30-15:45 Rm. 4813/4913 Regular Session WeC11 *Service Robotics 2*	14:30-15:45 Rm. 4211/4212 Forum WeC12 *Government Forum 3*
15:45-16:05 Coffee_Break											
16:05-17:20 Rm. 4011 Regular Session WeD1 *Soft Robotics 1*	16:05-17:20 Rm. 4111 Regular Session WeD2 *Motion and Path Planning 2*	16:05-17:20 Rm. 4311/4312 Regular Session WeD3 *Visual Tracking*	16:05-17:20 Rm. 4411/4412 Regular Session WeD4 *Slam 2*	16:05-17:20 Rm. 4511/4512 Regular Session WeD5 *Aerial Robot 4*	16:05-17:20 Rm. 4611/4612 Regular Session WeD6 *Semantic Understanding*	16:05-17:20 Rm. 4711/4712 Regular Session WeD7 *Manipulation Planning 2*	16:05-17:20 Rm. 4613/4713 Regular Session WeD8 *Humanoid Robots 3*	16:05-17:20 Rm. 4811/4812 Regular Session WeD9 *Biologically-Inspired Robots 3*	16:05-17:20 Rm. 4911/4912 Regular Session WeD10 *Surgical Robotics 2*	16:05-17:20 Rm. 4813/4913 Regular Session WeD11 *Marine Robotics*	16:05-17:20 Rm. 4211/4212 Special Event WeD12 *RAS Townhall Meeting*

19:00-21:00 - Grand Ballroom

Conference Dinner

	Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7	Track 8	Track 9	Track 10	Track 11	Forum 1	Forum 2

ICRA 2017 Technical Program   Thursday June 1, 2017

Track 1	Track 2	Track 3	Track 4	Track 5	Track 6	Track 7	Track 8	Track 9	Track 10	Track 11	Forum 1	Forum 2

08:20-09:20 Grand ballroom
Plenary 3
Framing the International Discussion on the Weaponization of Increasingly Autonomous Technologies - Kerstin Vignard (United Nations Institute for Disarmament Research)

| 09:30-10:45 Rm. 4011 Regular Session ThA1

 Soft Robotics 2 | 09:30-10:45 Rm. 4111 Regular Session ThA2

 Motion and Path Planning 3 | 09:30-10:45 Rm. 4311/4312 Regular Session ThA3

 Vision and Range Sensing 1 | 09:30-10:45 Rm. 4411/4412 Regular Session ThA4

 Slam 3 | 09:30-10:45 Rm. 4511/4512 Regular Session ThA5

 Aerial Robot 5 | 09:30-10:45 Rm. 4611/4612 Regular Session ThA6

 Object Detection and Segmentation | 09:30-10:45 Rm. 4711/4712 Regular Session ThA7

 Robot Motion Control | 09:30-10:45 Rm. 4613/4713 Regular Session ThA8

 Telerobotics and Teleoperation | 09:30-10:45 Rm. 4811/4812 Regular Session ThA9

 TRO Session - Multi-Modal Robot Design and Control | 09:30-10:45 Rm. 4911/4912 Regular Session ThA10

 Biorobotics | 09:30-10:45 Rm. 4813/4913 Regular Session ThA11

 Space Robotics | 09:30-10:45 Rm. 4211/4212

 Forum ThA12

 ASEAN & Emerging Country Forum 1 | 09:30-10:45 Grand ballroom

 Forum ThA13

 Public Forum 1 - ICRA X |

10:45-11:05 Coffee_Break

| 11:05-12:20 Rm. 4011 Regular Session ThB1

 Soft Robotics 3 | 11:05-12:20 Rm. 4111 Regular Session ThB2

 Motion and Path Planning 4 | 11:05-12:20 Rm. 4311/4312 Regular Session ThB3

 Vision and Range Sensing 2 | 11:05-12:20 Rm. 4411/4412 Regular Session ThB4

 Slam 4 | 11:05-12:20 Rm. 4511/4512 Regular Session ThB5

 Aerial Robot 6 | 11:05-12:20 Rm. 4611/4612 Regular Session ThB6

 Failure Detection and Recovery | 11:05-12:20 Rm. 4711/4712 Regular Session ThB7

 Robust and Adaptive Control | 11:05-12:20 Rm. 4613/4713 Regular Session ThB8

 Human Factors 1 | 11:05-12:20 Rm. 4811/4812 Regular Session ThB9

 Micro/Nano Robots 1 | 11:05-12:20 Rm. 4911/4912 Regular Session ThB10

 Physically Assistive Devices | 11:05-12:20 Rm. 4813/4913 Regular Session ThB11

 Parallel Robots | 11:05-12:20 Rm. 4211/4212

 Forum ThB12

 ASEAN & Emerging Country Forum 2 | 11:05-12:20 Grand ballroom

 Forum ThB13

 Public Forum 2 - ICRA X |

12:20-13:20 Lunch_Break

13:20-14:50 Grand ballroom
Award Ceremony

14:50-15:20 Grand ballroom Keynote 5 *An Operational Platform of Cloud Robotics - Bill Huang (Cloud Minds, China)*

15:20-15:50 Grand ballroom Keynote 6 *Model-Based Optimization for Humanoid and Wearable Robots - Katja Mombaur (University of Heidelberg, Germany)*

15:50-16:10   *Coffee_Break*

16:10-17:25 Rm. 4011 Regular Session ThC1	16:10-17:25 Rm. 4111 Regular Session ThC2	16:10-17:25 Rm. 4311/4312 Regular Session ThC3	16:10-17:25 Rm. 4411/4412 Regular Session ThC4	16:10-17:25 Rm. 4511/4512 Regular Session ThC5	16:10-17:25 Rm. 4611/4612 Regular Session ThC6	16:10-17:25 Rm. 4711/4712 Regular Session ThC7	16:10-17:25 Rm. 4613/4713 Regular Session ThC8	16:10-17:25 Rm. 4811/4812 Regular Session ThC9	16:10-17:25 Rm. 4911/4912 Regular Session ThC10	16:10-17:25 Rm. 4813/4913 Regular Session ThC11	16:10-17:25 Rm. 4211/4212 Forum ThC12
Soft Robotics 4	*Motion and Path Planning 5*	*Vision and Range Sensing 3*	*Slam 5*	*Aerial Robot 7*	*Probability and Statistical Methods*	*Calibration and Identification*	*Human Factors 2*	*Micro/Nano Robots 2*	*Prosthetics and Exoskeletons*	*Flexible Robots*	*Ethics Forum*

19:00-21:00 NIGHT SAFARI **Farewell Reception**

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ICRA 2017 Technical Program Friday June 2, 2017											
Full-Day Workshop 1	Full-Day Workshop 2	Full-Day Workshop 3	Full-Day Workshop 4	Full-Day Workshop 5	Full-Day Workshop 6	Full-Day Workshop 7	Full-Day Workshop 8	Full-Day Workshop 9	Full-Day Workshop 10	Full-Day Workshop 11	Full-Day Workshop 12
08:30-17:00 Rm. 4011 Full-Day Workshop FrW1 *Human Multi-Robot Systems Interaction*	08:30-17:00 Rm. 4111 Full-Day Workshop FrW2 *Biohybrid Machine by Small-Scale Robotics and Systems*	08:30-17:00 Rm. 4311/4312 Full-Day Workshop FrW3 *Learning and Control for Autonomous Manipulation Systems: The Role of Dimensionality Reduction*	08:30-17:00 Rm. 4411/4412 Full-Day Workshop FrW4 *Disaster Response Robots: Design Principles and Control for Effective Mobility and Manipulation*	08:30-17:00 Rm. 4511/4512 Full-Day Workshop FrW5 *Assistive Robotics: From the Natural to the Artificial and Back Again*	08:30-17:00 Rm. 4611/4612 Full-Day Workshop FrW6 *Innovative Haptic Interfaces Emerging from Soft Robotics*	08:30-17:00 Rm. 4711/4712 Full-Day Workshop FrW7 *Multi-Robot Perception-Driven Control and Planning*	08:30-17:00 Rm. 4613/4713 Full-Day Workshop FrW8 *Event-Based Vision*	08:30-17:00 Rm. 4811/4812 Full-Day Workshop FrW9 *AI in Automation*	08:30-17:00 Rm. 4911/4912 Full-Day Workshop FrW10 *C4 Surgical Robots: Compliant, Continuum, Cognitive, and Collaborative*	08:30-17:00 Rm. 4813/4913 Full-Day Workshop FrW11 *Robotics and Vehicular Technologies for Self-Driving Cars*	08:30-17:00 Rm. 4211/4212 Full-Day Workshop FrW12 *IC3 – Industry of the Future: Collaborative, Connected, Cognitive. Novel Approaches Stemming from Factory of the Future & Industry 4.0 Initiatives*