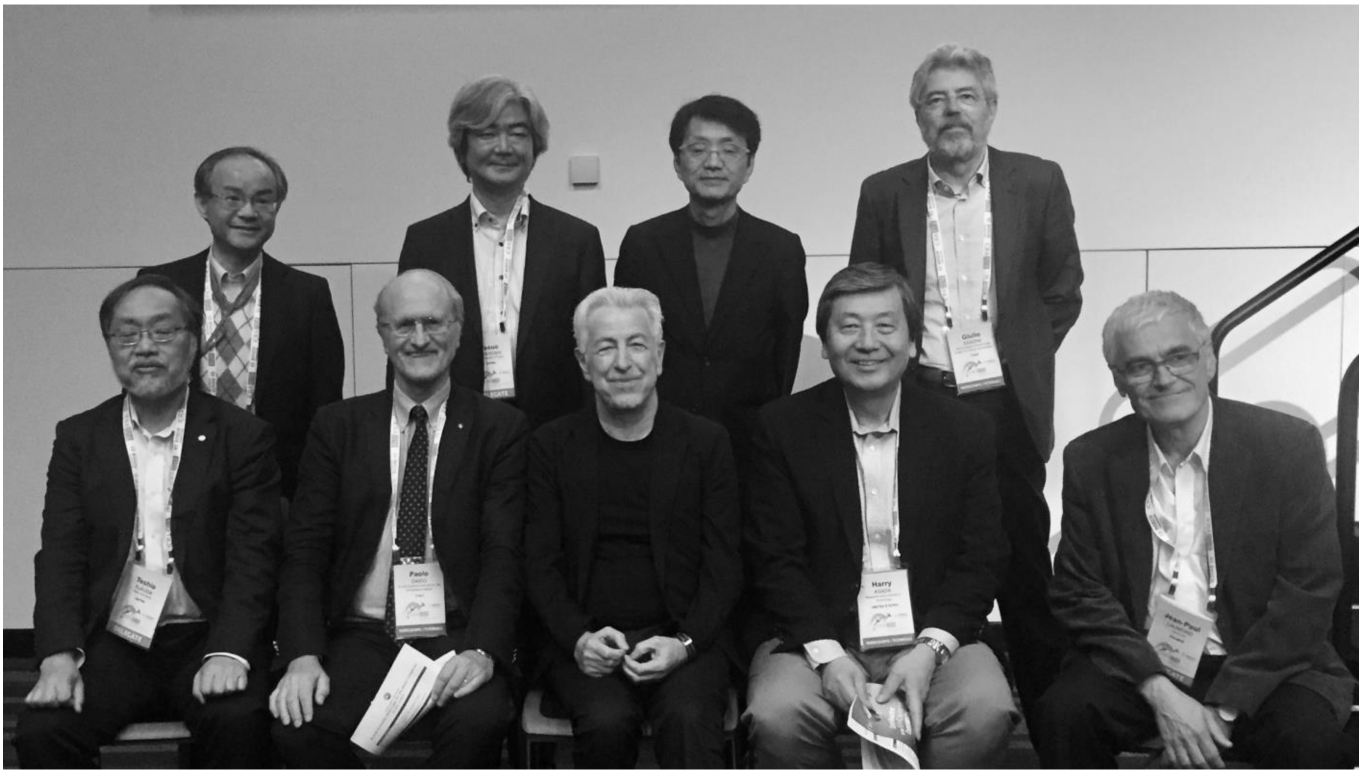
WORKSHOP ON

Grand Scientific Challenges for the Robot Companion of the Future

ICRA 2018 - May 21, 2018 - Brisbane (Australia)



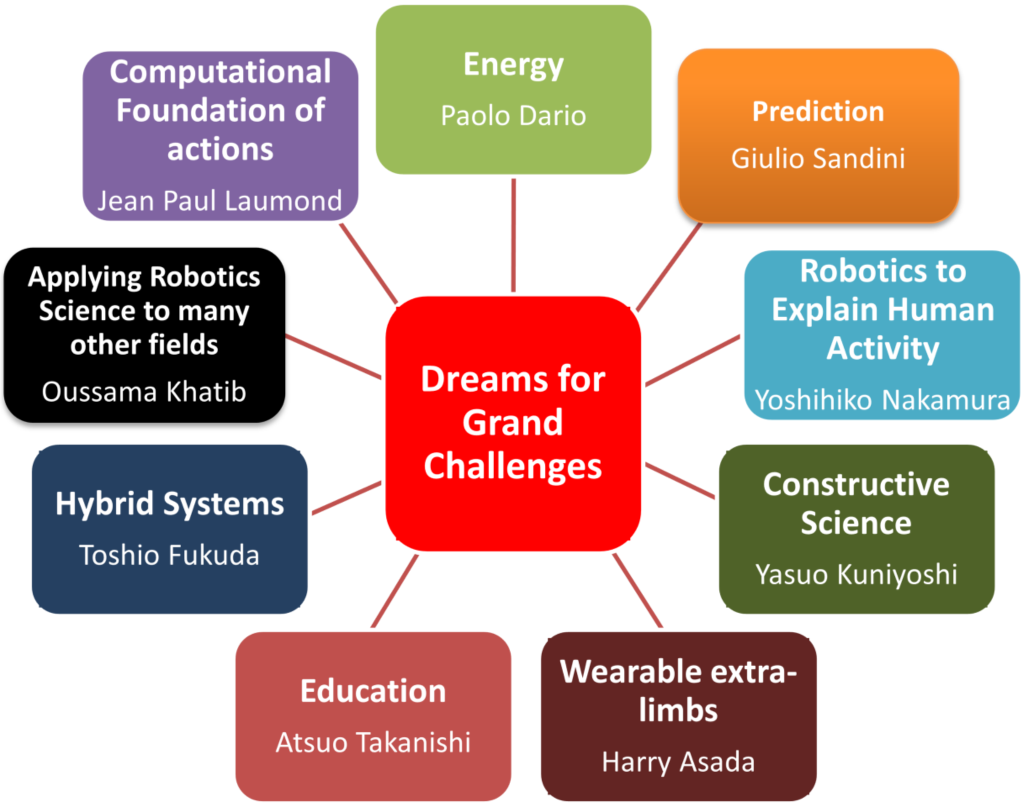
Objectives of the speakers of the workshop

The Robot Companion of the future will pursue a radically new design paradigm, grounded in the scientific studies of movement, behavior and intelligence in nature. This approach will allow achieving complex functionalities not only in new robot brains, but also in a new bodyware making limited use of computing resources, mass and energy, and able to exploit compliance instead of fighting it. The main objectives of this workshop are to offer new insights on the science and the technology enabling the next generations of Robot Companions, capable of overcoming the limitations of current robots in human daily-life scenarios.

The workshop introduced and addressed the grand challenges of science-grounded and bioinspired Robotics that aim to design and build new robots integrating soft bodyware, controlled by emergent behavior and orchestration, exploiting their partly compliant body, and using energy more efficiently.

The workshop also was an opportunity for discussing the challenge of the robot companion of the future as a global initiative of the international robotics community, by comparing national programs and analysing the opportunities for federated activities.

Grand Scientific Challenges according to the speakers of the workshop



Harry Asada

Can the Brain Support Wearable Extra Limbs?

Humans can perform dexterous manipulation by coordinating their two arms. They can also coordinate four limbs in complex activities. Can they control fifth and sixth limbs if extra robotic limbs are attached to their body? Can the brain support wearable extra limbs in performing a task together with the natural limbs? Here, we have found that human subjects can control two extra limbs together with the two natural arms, but not simultaneously. Through short-term training, human subjects learned to control two robotic limbs attached around the waist while performing a different task with their natural arms. They could move the two robotic limbs together, but not simultaneously with the natural arms. They paid attention back and forth to the robots and their own arms. Interestingly, however, the haptic feedback of the wearable robot to the human body can reduce the need for visual attention to the robotic limbs, so that the human can concentrate on the task at hand. Based on these scientific findings, we have designed and built various wearable extra limbs, including robot arms on the shoulder for performing a task on the ceiling, wearable extra fingers for assisting hemiplegic patients, and the Mantis Bot, extra limbs bracing the human working on the floor. These scientific findings and engineering design will open up the possibility that humans can possess and activate more than four limbs to augment the natural capabilities of their body.

Biosketch

H. Harry Asada is Ford Professor of Mechanical Engineering and Director of the Brit and Alex d'Arbeloff Laboratory for Information Systems and Technology in the Department of Mechanical Engineering, Massachusetts Institute of Technology (MIT), Cambridge, MA. He received the B.S., M.S., and Ph.D. degrees in precision engineering in 1973, 1975, and 1979, respectively, all from Kyoto University, Japan. He specializes in robotics, biological engineering, and system dynamics and control. His current robotics research includes neuro-motor control associated with wearable extra limbs and their applications to aircraft manufacturing, heavy industries, and prosthetics. His research in the bio area focuses on bio-integrated robots, where live cells and tissues are used as components. He received Best Paper Awards at the IEEE International Conference on Robotics and Automation (ICRA) in 1993, 1997, 1999, and 2010, the Best Application Paper Award at the 2017 IROS, the O. Hugo Schuck Best Paper Award from the American Control Council in 1985, and Best Journal Paper Awards from the Society of Instrument and Control Engineers in 1979, 1984, and 1990. He was the recipient of the 2011 Rufus Oldenburger Medal from ASME, the Henry Paynter Outstanding Researcher Award from ASME Dynamic Systems and Control in 1998, and the Ruth and Joel Spira Award for Distinguished Teaching from the School of Engineering, MIT. Dr. Asada is a Fellow of ASME.

Paolo Dario

Rethinking Robotics for the Robot Companion of the Future

The Robot Companion of the future will pursue a radically new design paradigm, grounded in the scientific studies of movement, behavior and intelligence in nature. This approach will allow achieving complex functionalities not only in new robot brains, but also in a new bodyware making limited use of computing resources, mass and energy, and able to exploit compliance instead of fighting it. Simplification mechanisms will be based on the concepts of embodied intelligence, morphological computation, simplexity, and evolutionary and developmental approaches. These concepts can be exploited to develop new scientific knowledge and new robots that can effectively negotiate natural environments, better interact with human beings as real "Companions", and provide services and support in a variety of real-world, real-life activities. Ultimately, the Companion Robots of the Future may foster a new wave of economic growth by boosting the deployment of ubiquitous robots and web-based robotic services.

Biosketch

Paolo Dario is Professor of Biomedical Robotics. He was and is visiting researcher and professor at several universities worldwide, including Tianjin University. His main research interests are in the fields of medical robotics and bio-robotics. He is the coordinator of many national and European projects, and the author of more than 500 scientific journal papers. He has served as a Member (2 terms) of the ISTAG (IST Advisory Group) of the EU, and as a Member of the Global Agenda Council on Robotics and Smart Devices of the World Economic Forum. Prof. Dario is an IEEE Fellow and he served as President of the IEEE Robotics and Automation Society in the years 2002-2003. He is also a Fellow of the European Society on Medical and Biological Engineering and a recipient of many honors and awards.

Oussama Khatib

The Age of Human-Robot Collaboration

Robotics is undergoing a major transformation in scope and dimension with accelerating impact on the economy, production, and culture of our global society. The generations of robots now being developed will increasingly touch people and their lives. They will explore, work, and interact with humans in their homes, workplaces, in new production systems, and in challenging field domains. The emerging robots will provide increased support in mining, underwater, hostile environments, as well as in domestic, health, industry, and service applications. Combining the experience and cognitive abilities of the human with the strength, dependability, reach, and endurance of robots will fuel a wide range of new robotic applications. The discussion focuses on design concepts, control architectures, task primitives and strategies that bring human modeling and skill understanding to the development of this new generation of collaborative robots.

Biosketch

Oussama Khatib received his PhD from Sup'Aero, Toulouse, France, in 1980. He is Professor of Computer Science and Director of the Robotics Laboratory at Stanford University. His research focuses on methodologies and technologies in human-centered robotics. He is a Fellow of IEEE, Co-Editor of the Springer Tracts in Advanced Robotics (STAR) series, and the Springer Handbook of Robotics. Professor Khatib is the President of the International Foundation of Robotics Research (IFRR). He is recipient of the IEEE RAS Pioneer Award, the George Saridis Leadership Award, the Distinguished Service Award, the Japan Robot Association (JARA) Award, the Rudolf Kalman Award, and the IEEE Technical Field Award. In 2018, Professor Khatib was elected to the National Academy of Engineering.

Jean-Paul Laumond

Principles of embodied locomotion

The talk reports on results issued from a multidisciplinary research action exploring the motor synergies of anthropomorphic walking. By combining the 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: 1) passive robot walkers, which are very efficient in terms of energy consumption, can be modeled by a simple rotating rimless wheel; 2) 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. We show how the center of mass and the head play complementary roles giving rise to the so-called Yoyo-Man model. This model opens new perspectives to explore the computational foundations of anthropomorphic walking.

Biosketch

Jean-Paul Laumond, IEEE Fellow, is a roboticist. He is Directeur de Recherche at LAAS-CNRS (team Gepetto) in Toulouse, France. His research is robot motion planning and control. In 2001 and 2002 he created and managed Kineo CAM, a spin-off company from LAAS-CNRS devoted to develop and market motion planning technology. Siemens acquired Kineo CAM in 2012. In 2006, he 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. He has published more than 150 papers in international journals and conferences in Robotics, Computer Science, Automatic Control and in Neurosciences. His current project Actanthrope (ERC-ADG 340050) is devoted to the computational foundations of anthropomorphic action.

He teaches Robotics at Ecole Normale Supérieure in Paris. He has been the 2011-2012 recipient of the Chaire Innovation technologique Liliane Bettencourt at Collège de France in Paris. He is the 2016 recipient of the IEEE Inaba Technical Award for Innovation Leading to Production. He is a member of the French Academy of Technologies and of the French Academy of Sciences.

Yoshihiko Nakamura

Models of musculoskeletal systems

The human whole body is a complex and hierarchical multi-physics system. Computer simulation of the human whole body is the grand challenge. The current focus of our study is on closing the loop of the neural system and the musculoskeletal system. Although the knowledge of the biomechanical structure of human body in every scale is well documented in anatomy, we do not know how the whole system works through their hierarchical and horizontal interactions. Mechanics and dynamics in robotics provide the tools for describing the complex system, while optimization and algorithm in robotics offer the means for solving the results of interactions. Study of brain science discovered the structure of neural system. The brain anatomy also shows the knowledge of the structure and of the connection among the local areas with interpretation of their functions. However, the pictures are still and static. While dynamics of neurons is mathematically well modelled, dynamical behaviour of the neuron pool remains unexplored. What kind of dynamic views will show up by connecting and closing the loop of the two dynamical systems, namely, the neural anatomy and the body anatomy? This talk will introduce our approach on modelling for the human whole body simulation.

Biosketch

Yoshihiko Nakamura is Professor at Department of Mechano-Informatics, School of Information Science and Technology, University of Tokyo. He received Ph.D from Kyoto University. He worked at Kyoto University as Assistant Professor, and at University of California, Santa Barbara as Associate Professor before joining University of Tokyo in 1991. Humanoid robotics, cognitive robotics, neuro musculoskeletal human modeling, biomedical systems, and their computational algorithms are his current fields of research. Dr. Nakamura served as President of IFToMM (2012-2015). He is Foreign Member of Academy of Engineering Science of Serbia, TUM Distinguished Affiliated Professor of Technische Universität München, Executive Member of International Foundation of Robotics Research, and Fellow of JSME, RSJ, IEEE, and World Academy of Art and Science.

Giulio Sandini

Humanizing Assistive Robots

In spite of the very fast advancements of robot technology and the general impression that personal robots will soon enter our everyday life to support activities of daily living, the social impact of personal robots is still very limited and the interaction between humans and robots is still very much based on a technology-based language of communication. This has created a discrepancy between the motoric abilities of the robots supporting the execution of human-like, dynamic and dexterous movements and their ability to understand the goals of human's actions and to assist humans in an anticipatory way (a fundamental requirement to assist a partner during even simple collaborative tasks). The result of this discrepancy is that the kind of assistance the robot can provide is constrained to reducing the effort or increasing the accuracy of the human in the loop through a real-time control. Although this is an important and useful robotic achievement, this kind of assistance is still far from the kind of intelligent assistance provided by a young apprentice while learning to support her/his master. What is missing is the cognitive ability to understand and follow the evolution of the task being executed by "reading" the actions of the human partners and to adopt to the most useful assistive actions (an adaptive behaviour based on anticipation and not only on contingent sensorimotor information).
During the talk I will argue that the ability to "read a human being" is the initial missing milestone for a robot to be able to effectively assist a human during activities of daily living whenever the role of the robot is to adapt its actions to the skills, pace, knowledge, fatigue of the human operator and not to be driven like a machine. I will also argue that to "read a human being" we need to take explicitly into consideration not only the overt messages exchanged during social interaction, such as speech or gestures, but also the covert messages embedded in the way humans move. The combination of covert and overt messages exchanged during interaction contribute significantly to our ability to anticipate intentions and to go "beyond real time".

Biosketch

Giulio Sandini is Founding Director of the Italian Institute of Technology and full professor of bioengineering at the University of Genoa. He was research fellow and assistant professor at the Scuola Normale Superiore in Pisa and Visiting Research Associate at the Department of Neurology of the Harvard Medical School. In 1992 he founded the LIRA-Lab (Laboratory for Integrated Advanced Robotics, www.liralab.it) at the University of Genova and in 1996 he was Visiting Scientist at the Artificial Intelligence Lab of MIT. He has been the coordinator of the EU-funded project RobotCub where a consortium of 11 research institutions in Europe gave birth to the iCub humanoid robot to investigate aspect of cognitive development in humans and robots.
In 2006 Giulio Sandini has been appointed Director of Research at the Italian Institute of Technology where he has established the department of Robotics, Brain and Cognitive Sciences.
The website: www.iit.it/rbcs

Qing Shi

System Design of a Miniature Robotic Rat for Interaction with Laboratory Rats

Inspired by biomimetics, bioinspired robots have offered novel methodologies for study of the response of an animal to stimuli from conspecifics or heterospecifics. Rodents such as rats or mice are emulated because they are widely available and easily handled and maintained. In particular, behavioural tests such social interaction test among two or more rats play a critical role in characterizing rat sociality. Although many studies on social interactions are performed with multiple rat subjects, it is difficult to control and assess their behavioural indices because of individual differences. To address this problem, we replace a real rat with a robotic rat to perform social interactions with other tested rats in an open field. In such scenarios, the robotic rat is expected to be developed to closely resemble the laboratory rat in terms of its morphology and modes of typical actions (e.g. moving, rearing, mounting, body grooming). In this talk, we present our current progress on the system design of an agile, flexible and multifunctional robot (named WR-5M) with similar morphology and aesthesis to a laboratory rat. The skeletal structure and morphology of WR-5M were determined based on systematic observation of the rat behaviour demonstrated in X-ray video images. The designed robot was able to mimic several rat actions (e.g., rearing, mounting, body grooming) with gestures that were identical to those of rats. In addition, the robot was endowed with ultra-tiny cameras and whiskers to mimic rat-like perception.

Biosketch

Qing Shi received the B.S. degree in Mechatronics from Beijing Institute of Technology, Beijing, China, in 2006, and the Ph.D. degree in Biomedical Engineering from Waseda University, Japan, in 2012. Since 2013 he has been a Lecturer, and now an Associate Professor at Beijing Institute of Technology. His research interests are focused on biorobotics, mechatronic systems, computer vision, and micro/nano robotics. Dr. Shi has published more than 50 international journal/conference papers, and has received Best Journal Paper Award of Advanced Robotics (2015), and Best Cognitive Robotics Paper Finalist of ICRA 2014. He is currently the Associate Editor of ROBOMECH Journal, and the Secretary of IEEE Beijing Section Robotics and Automation Society Chapter. Additionally, he has served as Associate Editor of IROS2016, ICRA2017 and ICRA 2018, Guest Editor of IEEE Transactions on Nanotechnology and Applied Sciences, Program Co-Chair of 2017 IEEE International Conference on Cyborg and Bionic Systems.

Atsuo Takanishi

Humanoid Robotics and Its Applications

Even though the market size is still small at this moment, one can now easily expect that applications of robots will expand into the first and the third industrial fields as one of the important technologies to support our society in the 21st century. There also raises strong anticipations in Japan that robots for the personal use, "Robot Companions," will coexist with humans and provide supports such as the assistance for the housework, care of the aged and the physically handicapped and/or retailing/transportation/building-clearing, etc., since Japan is one the fastest aging societies in the world. Consequently, humanoids/human-like-robots have been treated as subjects of robotics researches in Japan such as a research tool for human science, an entertainment/mental-commit robot or an assistant/agent for humans in the living environment and other possible cases. Over the last two decades, some manufactures and telecommunication companies including famous global ones started to develop prototypes or even mass production robots for the purposes mentioned above, such as TOYOTA, HONDA, KAWASAKI, SoftBank, etc. In the workshop I will introduce our researches on humanoid robots and their applications such as bipedal walking/running humanoids, medical simulator humanoids and disaster rescuing four-limbed robots, etc. Please see our web page for more detailed information: http://www.takanishi.mech.waseda.ac.jp.

Biosketch

ATSUO TAKANISHI is a Professor of the Department of Modern Mechanical Engineering as well as the Director of the Humanoid Robotics Institute, Waseda University in Tokyo, Japan. He received the B.S.E. degree in 1980, the M.S.E. in 1982 and the Ph.D. in 1988, all in Mechanical Engineering from Waseda University. His current researches are related to Humanoid Robotics and its applications, such as the biped walking/running, the emotion expression, the musical instrument player, the medical training simulation humanoids, etc. He recently initiated new projects on disaster response four limbed robots and wild animal monitoring mobile robots.

He was the former President of the Robotics Society of Japan (RSJ) from 2015 to 2016, and is currently the Chairman of the Japanese Council of the International Federation for the Promotion of Mechanism and Machine Science (Jc-IFToMM) and a Vice President of the Fukuoka Prefectural Robotics and Advanced System Industry Development Council, etc. He is a fellow of RSJ, the Japanese Society of Mechanical Engineers (JSME) and a senior member of IEEE.

Yasuo Kuniyoshi

Emergence and Development of Embodied Behavior and Cognition in Simulated Human Fetus and Infant - Towards Next Generation Human AI/Robots

Recently many problems are pointed out with current AI systems concerning their reliability and appropriateness. The problems have their roots on the fundamental framework as optimization of input-output systems with regard to large but limited data sets. This severely lacks essential accounts for open-ended dynamic real wold interaction and alignment to human nature. Therefore, revealing new principles of real world human intelligence is an urgent issue. We propose that constructive investigation of the very early human development in the context of emergence and development of behaviour and cognition from embodied interaction is crucial.

Development is a continuous causal process involving complex interaction between genes, body, nervous system and environment. Although the whole process may be too complicated, fetal interaction and development can be relatively more tractable to model. From a dynamical systems point of view, the beginning part of the temporal development trajectory provides an important information about the underlying principles governing the developmental dynamics. We constructed a computer simulation model of a human fetus. It consists of a musculo-skeletal body, uterus, and basic nervous system. It exhibits spontaneous motor development and sensory-motor map organization comparable to human data. Also, by changing the model parameters, we can simulate “atypical” development. Our series of experiments shows that sensory-motor experiences in the fetal period can be crucial to the formation of body representations and multi-modal sensory integration, which are significantly affected under "preterm birth" conditions, providing new insights about the developmental origins of social cognition and autism spectrum disorders. This approach continues on to target infant development on actual robotic platforms.

Biosketch

Yasuo Kuniyoshi received Ph.D. from The University of Tokyo in 1991 and joined Electrotechnical Laboratory, AIST, MITI, Japan. From 1996 to 1997 he was a Visiting Scholar at MIT AI Lab. In 2001 he was appointed as an Associate Professor and then full Professor in 2005 at The University of Tokyo. He is also the Director of RIKEN CBS-Toyota Collaboration Center since 2012, and the Director of Next Generation AI Research Center of The University of Tokyo since 2016.

He published over 290 refereed academic papers and received IJCAI 93 Outstanding Paper Award, Gold Medal "Tokyo Techno-Forum21" Award, Best Paper Awards from Robotics Society of Japan, IEEE ROBIO T.-J. Tarn Best Paper Award in Robotics, Okawa Publications Prize, and other awards.

He is a Fellow of Robotics Society of Japan, Chairman of Executive Board of Japan Society of Developmental Neuroscience and a member of IEEE, Science Council of Japan (affiliate), Japan Society of Artificial Intelligence, Information Processing Society of Japan, Japanese Society of Baby Science.

For further information about his research, visit http://www.isi.imi.i.u-tokyo.ac.jp/ and http://www.ai.u-tokyo.ac.jp/

This Workshop is organized by the FLAG-ERA JTC2016 RoboCom++ Project, and is supported by the IEEE RAS TCs on Humanoid Robotics; on Biorobotics; on Human Robot Interaction & Coordination; on Human Movement Understanding; on Cyborg & Bionic Systems; on Energy, Environment, and Safety Issues in Robotics and Automation; on Cognitive Robotics; and on Algorithms for Planning and Control of Robot Motion