DIGEST BOOK for

ROMANSY 2020 ONLINE

23rd CISM IFToMM Symposium on Robot Design, Dynamics and Control

September 20-24, 2020

Organized by

Japanese Council of IFToMM
International Centre for Mechanical Sciences (CISM)
International Federation for the Promotion of Mechanism and Machine Science (IFToMM)

Welcome message

Welcome to ROMANSY2020!
It is a great honor and pleasure for us to organize the ROMANSY Symposium, which is the first established conference that emphasizes the theory and research of robotics, rather than the industrial aspect. This series symposium is co-sponsored by CISM (International Centre for Mechanical Science) and IFToMM (International Federation for the Promotion of Mechanism and Machine Science), and is technically supported by TC (Technical Committee) for Robotics and Mechatronics, IFToMM.
Since the decision of the venue of the 23rd symposium by the ISC (International Scientific Committee) of ROMANSY on June 25, 2018 during the 22nd ROMANSY2018 held in Rennes, France, we, the organizing committee of ROMANSY2020, have done our best to organize the symposium in order that an environment and setting for meaningful technical and personal interactions among participants would be provided.
We received seventy-nine papers of high quality from sixteen countries, providing a vision of the evolution of the robotics disciplines and signaling new directions in which these disciplines are foreseen to develop. The paper reviews have been done quite well thanks to the efforts of the reviewers, who are members of ISC and AB (advisory board) of ROMANSY, members of TC for Robotics and Mechatronics, IFToMM, and active researchers in this community. Finally, sixty-seven papers are presented at the symposium and are included in the Proceedings published from Springer.
In addition to the technical presentations of the accepted papers, four keynote speeches by outstanding researchers and engineers related to Robotics and technical presentations by the supporting companies are planned in this symposium.
Initially, we would like to welcome all the participants in Sapporo, Hokkaido, a very nice place located in the north island of Japan, by arranging technical and social events as well as technical sessions. However, unfortunately, due to the COVID-19 crisis, we have decided to change the symposium style to online one. This decision has been properly made thanks to a lot of encouraging advises, comments and discussions from the community, and has been officially supported by ISC of ROMANSY. Since this is the first symposium of ROMANSY by the online style, we would like to explore a new symposium style in the new life style after COVID-19.
We wish you have a great time during the online ROMANSY2020 and continue to participate in the coming ROMANSY symposiums for developing the theory and practice of robotics, as well as of mechanical sciences under the activity of this community.

With best regards and keep you safe and healthy.

On behalf of the Organizing Committee of ROMANSY2020
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The ROMANSY 2020 is supported by the IFToMM TCs for Robotics and Mechatronics, Computational Kinematics, and Linkage and Mechanical Control.

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Scope

The scope of ROMANSY 2020 is in topics related to robotics within aspects of theory, design, practice and industrial applications, including but not limited to:
- novel robot design and robot modules/components;
- personal, service, medical, space and rescue robots;
- humanoid robots, bio-robotics, multi-robot, embodied multi-agent systems;
- challenges in control, modeling, kinematical and dynamical analysis of robotic systems;
- innovations in sensor systems for robots and perception;
- biomechanical problems and education in robotics.

Proceedings

Papers are included in the conference proceedings that are published in Springer CISM series, a Web of Science and Scopus indexed series.

Important Dates

Paper submission due date	March 6, 2020
Paper acceptance notification due date	April 30, 2020
Final paper submission due date	May 20, 2020
Sessions of the symposium	September 20-24, 2020

Registration Fees / Extra Page Charge

Delegate from IFToMM MO*	JPY 15,000 (until Sept 4, 2020) / JPY 20,000 (from Sept 5, 2020)
Delegate from non-IFToMM MO*	JPY 25,000 (until Sept 4, 2020) / JPY 30,000 (from Sept 5, 2020)
Student**	JPY 5,000 (until Sept 4, 2020) / JPY 15,000 (from Sept 5, 2020)
Extra page charge	JPY 10,000/page (up to two extra pages are acceptable)

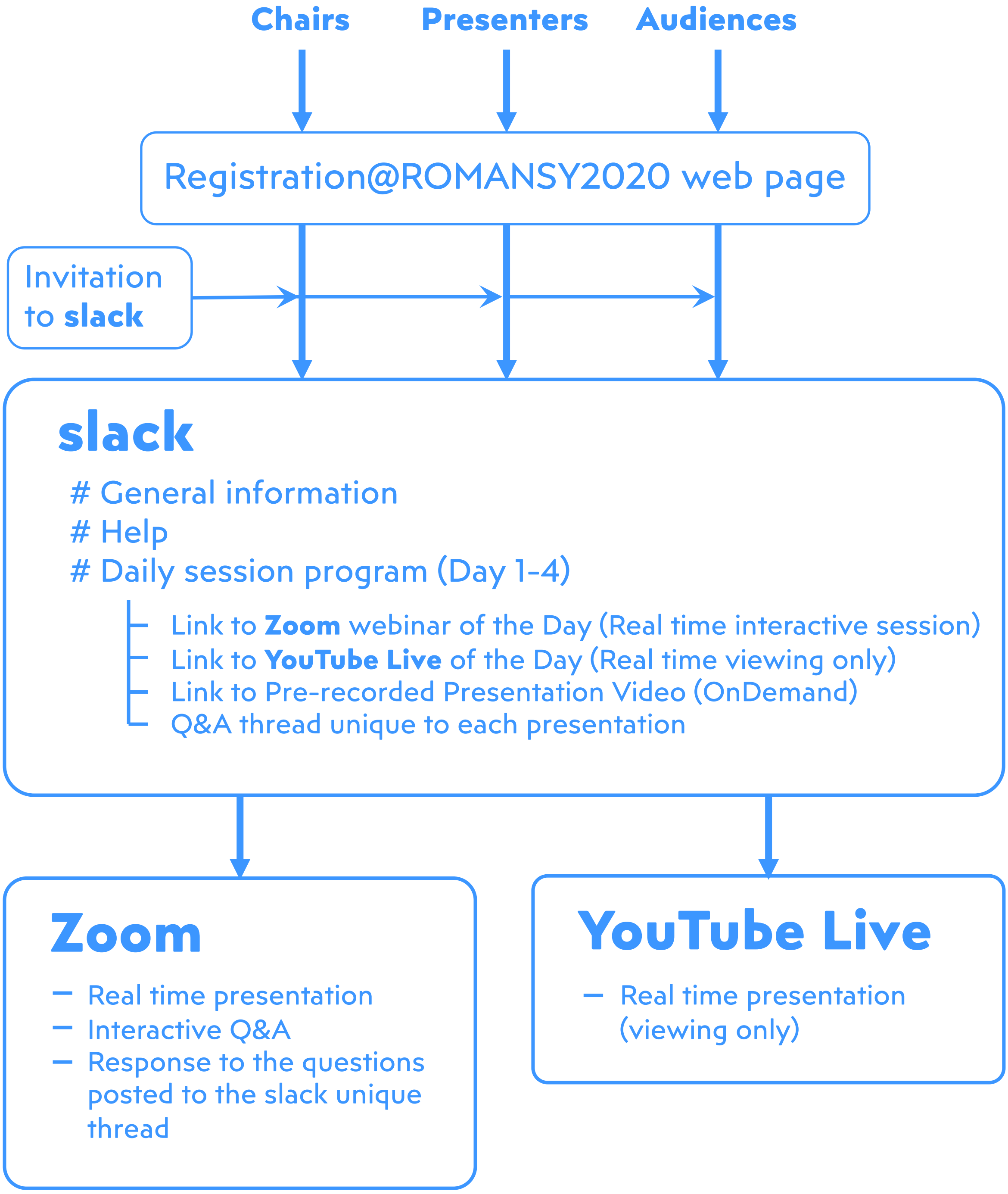
Registration fees include the attendance to the online conference, a copy of the book proceedings that will be sent by post to the designated address given at the time of registration, access to the online proceedings at the time of the conference. Early registration fees are applicable until September 4, 2020 (Japan Standard Time, UTC+9).
* Two papers may be presented. ** One paper may be presented.

Young Delegate Program (YDP)

The purpose of YDP is to provide assistance to young scientists and engineers so that they may participate in IFToMM technical conferences. Up to fifty percent of the total cost of registration fees, transportation, board and lodging is available to participants who are not fully supported by their own institutions. ROMANSY 2020 has obtained support from IFToMM Executive Council for 3 grants.

Venue in Virtual

The ROMANSY 2020 is held online on slack. To make the most of your virtual ROMANSY 2020 experience, register for the symposium. You will get an invitation e-mail to the ROMANSY2020@slack from the symposium secretary!



Keynote Speakers

Dr. Xiaolong Feng

Business Research Manager at ABB Robotics

Towards Autonomous Robots

08:20 on September 21 (New York Time, UTC-4)
13:20 on September 21 (London Time, UTC+1)
21:20 on September 21 (Tokyo Time, UTC+9)

From 2019, Dr. Xiaolong Feng works as a Business Research Manager at ABB Robotics and Discrete Automation Business, responsible for a global team with focus on long-term robotics research. Between 2015 and 2018, he served as a Global Research Area Manager at ABB Corporate Research, responsible for Mechatronics research in industrial and service robotics and for long-term and fundamental research in Mechanics for all Divisions at ABB. In 2014, he was promoted as a Corporate Research Fellow at ABB Corporate Research in Optimal Mechanical Design. Between 2019 and 2014, he worked as a Senior Principal Scientist in Mechatronic Design at ABB Corporate Research Center in Sweden. He worked with modeling, simulation, design, optimization of industrial robotic manipulators between 2000 and 2014. In addition, he worked as a project manager between 2002 and 2014 in a number of large research projects in the area of efficient and optimal design of industrial robot manipulators. His academia merits include: He received Ph.D. at Stockholm University in 1998 in the research area of modeling and simulation of Quantum Mechanical systems. He was awarded Docent in Machine Design at Linköping University in 2012. He worked also as an adjunct professor at Linköping University between 2012 and 2019. He has about 50 scientific publications in journals and proceedings.

The increasing demand of flexibility of robotic automation in discrete manufacturing industry and the increasing need in robotic assistance solutions in healthcare, professional elderly homes, restaurants and in domestic environment require increasing level of autonomy of future robots – future autonomous robots. A future autonomous robot is intelligent, mobile, connected and safe that can work together with humans in dynamic and unstructured environment. Future autonomous robots will be enabled by four cornerstone technologies: Intelligence, Safety for collaboration, Mobility and Connectivity. In this presentation, the identified four cornerstone technologies will be discussed. A number of major trends in technology development that would become key enablers for these cornerstones will be summarized. This presentation will focus specifically on the presentation of research progress in two of the cornerstone technology areas, namely intelligence and mobility. The presented research progresses are achieved either by ABB global research teams or by our research partners in academia. In the intelligence research area, the progress of our research activities on several levels of intelligence will be presented: from introducing intelligence of the finger tip of a robotic gripper, AI based perception, autonomous grasping, to high level end to end learning methodology. In the mobility research area, the research progress of the following topics will be addressed: Multimodal sensing and advanced navigation, semantic SLAM, and ROS drive for motion planning and control of a mobile manipulator, a Mobile YuMi robot, developed by ABB.

Dr. Natsuki Yamanobe

Senior Researcher at National Institute of Advanced Industrial Science & Technology (AIST)

How should robots move to work together with humans?

04:00 on September 22 (New York Time, UTC-4)
09:00 on September 22 (London Time, UTC+1)
17:00 on September 22 (Tokyo Time, UTC+9)

Dr. Natsuki Yamanobe is a senior researcher of Industrial Cyber-Physical Systems Research Center at the National Institute of Advanced Industrial Science and Technology (AIST) and a guest associate professor at Tokyo University of Agriculture and Technology. She received her M.E. and Ph.D. degrees from the University of Tokyo in 2004 and 2007, respectively. In 2007 she started with AIST. For one year from 2014 to 2015 she was a visiting researcher at Karlsruhe Institute of Technology. Her research interests include robotic manipulation, human-robot interaction, skill analysis/transfer for dexterous manipulation.

Recently, co-worker scenarios where robots and humans work together sharing a workspace, became a topic of great interest also in manufacturing fields. What are the requirements of co-worker robots? In addition to the efficiency, robots should behave so as to be perceived safe and comfortable by the humans working together with them to ensure their acceptance. In this talk, I would like to present several works conducted to know what aspects of robot's behavior affect human's feelings from the viewpoint of common sense, semantics, and more automatic emotions like fear and anxiety. The framework of a cyber-physical system for human-robot collaboration is also introduced. The whole situation including environment, humans, and robots is continuously recognized and expressed in a cyber space, where the next possible situations are simulated, and orders for the robots are planned for a comfortable collaboration.

Prof. Dongheui Lee

Associate Professor at the Technical University of Munich, Director at the German Aerospace Center (DLR)

Towards cognition enabled assistive robots

09:00 on September 23 (New York Time, UTC-4)
14:00 on September 23 (London Time, UTC+1)
22:00 on September 23 (Tokyo Time, UTC+9)

Professor Dongheui Lee is Associate Professor of Human-centered Assistive Robotics at the TUM Department of Electrical and Computer Engineering. She is also director of a Human-centered assistive robotics group at the German Aerospace Center (DLR). Her research interests include human motion understanding, human robot interaction, machine learning in robotics, and assistive robotics. Prior to her appointment as Associate Professor, she was an Assistant Professor at TUM (2009-2017), Project Assistant Professor at the University of Tokyo (2007-2009), and a research scientist at the Korea Institute of Science and Technology (KIST) (2001-2004). After completing her B.S. (2001) and M.S. (2003) degrees in mechanical engineering at Kyung Hee University, Korea, she went on to obtain a PhD degree from the department of Mechano-Informatics, University of Tokyo, Japan in 2007. She was awarded a Carl von Linde Fellowship at the TUM Institute for Advanced Study (2011) and a Helmholtz professorship prize (2015). She is coordinator of both the euRobotics Topic Group on physical Human Robot Interaction and of the TUM Center of Competence Robotics, Autonomy and Interaction.

As a fundamental cornerstone in the development of intelligent robotic assistants, the research community on robot learning has addressed autonomous motor skill learning and control in complex task scenarios. Imitation learning provides an efficient way to learn new skills through human guidance, which can reduce time and cost to program the robot. Robot learning architectures can provide a comprehensive framework for learning, recognition and reproduction of whole body motions. The inference mechanism can be applied not only to learn the robot's free body motion but also to learn physical interaction tasks, including human robot interaction. I will give examples of cognition enabled assistive robotics, including enhancement of human-robot cooperation tasks over time and intuitive programming co-bots in industrial setting.

Prof. Masaaki Wada

Professor at Future University Hakodate

Smart fisheries in Japan, toward the sustainable fisheries

04:00 on September 24 (New York Time, UTC-4)
09:00 on September 24 (London Time, UTC+1)
17:00 on September 24 (Tokyo Time, UTC+9)

Dr. Masaaki Wada is a professor of Future University Hakodate, Japan. He received Ph.D. in the field of Marine Environment and Resources at the Graduate School of Fisheries Sciences, Hokkaido University. His main research interest is in smart fisheries based on information and communication technology. From 1993 to 2004, he was an engineer in Towa Denki Seisakusho Co., Ltd., Hakodate, Japan. Since 2005, he has been in Future University Hakodate. He is a member of the IEEE and IPSJ. He received Minister of Internal Affairs and Communications Award in 2016.

The global fisheries production exceeded 200 million ton in 2017. In particular, aquaculture production has been increasing year by year, and overtook capture production in 2013. Contrary to the global trends, capture production accounts for three-quarters of fisheries production in Japan. In the case of capture, we cannot achieve the sustainable fisheries without resource management. However, the advanced technologies of fishery equipment such as acoustic sonar has led to increase the fishing pressures and decrease the resources. In 2019, Japan Fisheries Agency launched a project of smart fisheries toward the sustainable fisheries. In this lecture, as a local topic in Hokkaido, I will introduce some practices of utilizing these advanced technologies not for over catch but for appropriate catch.

Program at a glance

NYC : New York City (UTC-4) LON : London (UTC+1) TYO : Tokyo (UTC+9)

DAY 1 : Monday, 21 September 2020

NYC	LON	TYO	
08:00	13:00	21:00	Opening Session
08:20	13:20	21:20	Keynote Speech 1: Towards Autonomous Robots Dr. Xiaolong Feng (ABB Robotics)
09:20	14:40	22:40	Technical Session 1

DAY 2 : Tuesday, 22 September 2020

NYC	LON	TYO	
01:00	06:00	14:00	Technical Session 2
04:00	09:00	17:00	Keynote Speech 2: How should robots move to work together with humans? Dr. Natsuki Yamanobe (AIST)
05:00	10:00	18:00	Technical Session 3
07:00	12:00	20:00	Industry Session 1
07:40	12:40	20:40	Technical Session 4
10:00	15:00	23:00	ISC/AB Meeting

DAY 3 : Wednesday, 23 September 2020

NYC	LON	TYO	
00:30	05:30	13:30	Technical Session 5
02:20	07:20	15:20	Technical Session 6
04:50	09:50	17:50	Technical Session 7
07:00	12:00	20:00	Industry Session 2
07:30	12:30	20:30	Technical Session 8
09:00	14:00	22:00	Keynote Speech 3: Towards cognition enabled assistive robots Prof. Dongheui Lee (Technical University of Munich, DLR)

DAY 4 : Thursday, 24 September 2020

NYC	LON	TYO	
00:30	05:30	13:30	Technical Session 9
02:00	07:00	15:00	Technical Session 10
04:00	09:00	17:00	Keynote Speech 4: Smart fisheries in Japan, toward the sustainable fisheries Prof. Masaaki Wada (Future University Hakodate)
05:10	10:10	18:10	Technical Session 11
07:00	12:00	20:00	Technical Session 12
09:20	14:20	22:20	Award Ceremony
10:00	15:00	22:40	Closing Session

Session Program

DAY 1 : Monday, 21 September 2020

NYC	LON	TYO	
08:00	13:00	21:00	**Opening Session**

Keynote Speech 1 (Chair: Jorge Solis)

NY	LON	JPN	
08:20	13:20	21:20	**Towards Autonomous Robots** Dr. Xiaolong Feng (ABB Robotics)

Technical Session 1 (Chair: Chin-Hsing Kuo and Yukio Takeda)

NYC	LON	TYO	
09:20	14:20	22:20	#56 **Gravity Compensation of Delta Parallel Robot Using a Gear-Spring Mechanism** Vu Linh Nguyen, Chin-Hsing Kuo and Chyi-Yeu Lin
09:40	14:40	22:40	#68 **Wire-pulling Mechanism with Embedded Soft Tubes for Robot Tongue** Nobutsuna Endo
10:00	15:00	23:00	#73 **Development of a Climbing-Robot for Spruce pruning: preliminary design and first results** Giovanni Carabin, Davide Emanuelli, Raimondo Gallo, Fabrizio Mazzetto and Renato Vidoni
10:20	15:20	23:20	#41 **Preliminary Design and Modeling of a Robot for Pipe Navigation with a Novel Wheel-Leg Architecture** Carl Nelson
10:40	15:40	23:40	#65 **Design and construction of the Dragonball** Bir Bikram Dey and Michael Jenkin

DAY 2 : Tuesday, 22 September 2020

Technical Session 2 (Chair: Masaharu Komori and Kenjiro Takemura)

NYC	LON	TYO	
01:00	06:00	14:00	#86 **Static Force Analysis of an Omnidirectional Mobile Robot with Wheels Connected by Passive Sliding Joints** Tatsuro Terakawa and Masaharu Komori
01:20	06:20	14:20	#93 **Development of Robust Ridge Detection Method and Control System for Autonomous Navigation of Mobile Robot in Agricultural Farm** Shunsuke Fujita, Takanori Emaru Ankit Ravankar and Yukinori Kobayashi
01:40	06:40	14:40	#50 **Singularity free mode changes of a redundantly driven two limbs six-dof parallel robot** Takashi Harada and Yuta Kunishige
02:00	07:00	15:00	#82 **Motion Synthesis Using Low-dimensional Feature Space and Its Application to Inverse Optimal Control** Soya Shimizu, Ko Ayusawa and Gentian Venture
02:20	07:20	15:20	#99 **Maximal Output Admissible Set of Foot Position Control in Humanoid Walking** Ko Yamamoto, Ryo Yanase and Yoshihiko Nakamura
02:40	07:40	15:40	#100 **A New Method of Climbing Downstairs by Changing Layers of Gears of Planetary Wheels for Wheelchair** Tianci Jiang and Eiichiro Tanaka
03:00	08:00	16:00	#87 **Investigation of Parallel Connection Circuit by Hydraulic Direct-Drive System for Biped Humanoid Robot Focusing on Human Running Motion** Hideki Mizukami, Takuya Otani, Juri Shimizu, Kenji Hashimoto, Masanori Sakaguchi, Yasuo Kawakami, Hun-Ok Lim and Atsuo Takanishi
03:20	08:20	16:20	#102 **Function Approximation Technique Based Immersion and Invariance Control for An Underactuated Tower Crane System** Yang Bai and Mikhail Svinin

Keynote Speech 2 (Chair: Yukio Takeda)

NYC	LON	TYO	
04:00	09:00	17:00	**How should robots move to work together with humans?** Dr. Natsuki Yamanobe (National Institute of Advanced Industrial Science & Technology (AIST))

Technical Session 3 (Chair: Tetsuyou Watanabe and Jorge Solis)

NYC	LON	TYO	
05:00	10:00	18:00	#106 **Dynamically-Feasible Trajectories for a Cable-Suspended Robot Performing Throwing Operations** Deng Lin, Giovanni Mottola, Marco Carricato, Xiaoling Jiang and Qinchuan Li
05:20	10:20	18:20	#39 **Development of an Off-Board Vision-based control for a Micro Aerial Vehicle** Jorge Solis, Christoffer Karlsson and Kristoffer Richardsson
05:40	10:40	18:40	#72 **Stiffness modeling of planar robotic manipulators: model reduction and identifiability of parameters** Shamil Mamedov, Dmitry Popov, Stanislav Mikhel, Alexandr Klimchik and Anatol Pashkevich
06:00	11:00	19:00	#57 **Proposition of on-line velocity scaling algorithm for task space trajectories** Marek Wojtyra and Łukasz Woliński
06:20	11:20	19:20	#62 **Braking of a solid body supported by two supports on a horizontal rough plane** Marat Dosaev, Vitaly Samsonov, Liubov Klimina, Yury Selyutskiy, Boris Lokshin and Shyh-Shin Hwang

Industry Session 1

NYC	LON	TYO	
07:00	12:00	20:00	Mitsubishi Electric Corporation Origin Inc.

Technical Session 4 (Chair: Yoshihiro Kai and Sebastien Briot)

NYC	LON	TYO	
07:40	12:40	20:40	#103 **Dynamic Modeling and Controller Design of a novel aerial grasping robot** Zhongmou Li, Xiaoxiao Song, Vincent Bégoc, Abdelhamid Chriette and Isabelle Fantoni
08:00	13:00	21:00	#37 **Control-based Design of a DELTA robot** Minglei Zhu, Abdelhamid Chriette and Sebastien Briot
08:20	13:20	21:20	#94 **An Analytical Formulation for the Geometrico-static Problem of Continuum Planar Parallel Robots** Federico Zaccaria, Sébastien Briot, M. Taha Chikhaoui, Edoardo Idà and Marco Carricato
08:40	13:40	21:40	#59 **Stability Analysis and Reconfiguration Strategy for Multi-agent D-formation Control** Alessandro Colotti, Angelo Cenedese, Sébastien Briot, Isabelle Fantoni and Alexandre Goldsztejn
09:00	14:00	22:00	#71 **Trajectory Planning Strategy for Multidirectional Wire-Arc Additive Manufacturing** Markus Schmitz, Carlo Weidemann, Burkhard Corves and Mathias Huesing
09:20	14:20	22:20	#31 **Control System Design for Human Assisting Robot** Teresa Zielinska and Michele Tartari
09:40	14:40	22:40	#64 **Workspace Analysis and Torque Optimization on a Schönflies-Motion Generator** Bruno Belzile and Jorge Angeles
10:00	15:00	23:00	**ISC/AB Meeting**

DAY 3 : Wednesday, 23 September 2020

Technical Session 5 (Chair: Nobuyuki Iwatsuki and Hidetsugu Terada)

NYC	LON	TYO	
00:30	05:30	13:30	#98 **Static Analysis and Design of Extendable Mechanism Inspired by Origami Structure Based on Non-Overconstrained Kinematically Equivalent Mechanism** Reiji Ando, Hiroshi Matsuo, Daisuke Matsuura, Yusuke Sugahara and Yukio Takeda
00:50	05:50	13:50	#49 **A Semi-Automatic Type Synthesis of a Closed-loop Spatial Path-Generator** Naoto Kimura and Nobuyuki Iwatsuki
01:10	06:10	14:10	#83 **Development of small robot with Inline Archimedean Screw Mechanism that can move through wetlands** Ko Matsuhiro, Katsuaki Tanaka, Shou Inoue, Tingting Zhong, Kazuki Kida, Yusuke Sugahara, Atsuo Takanishi and Hiroyuki Ishii
01:30	06:30	14:30	#88 **Development of a trapezoidal leaf spring for a small and light variable joint stiffness mechanism** Hiroki Mineshita, Takuya Otani, Kenji Hashimoto, Masanori Sakaguchi, Yasuo Kawakami, Hun-Ok Lim and Atsuo Takanishi
01:50	06:50	14:50	#34 **Development of Switchable Wearable Robot for Rehabilitation After the Surgery of Knee** Koji Makino, Teppei Ogura, Masahiro Nakamura and Hidetsugu Terada

Technical Session 6 (Chair: Akio Yamamoto and Gentiane Venture)

NYC	LON	TYO	
02:20	07:20	15:20	#84 **Model-based Dynamic Human Tracking and Reconstruction During Dynamic SLAM** Huayan Zhang, Tianwei Zhang and Lei Zhang
02:40	07:40	15:40	#89 **Connecting MATLAB/Octave to perceptual, cognitive and control components for the development of intelligent robotic systems** Enrique Coronado, Liz Rincon and Gentiane Venture
03:00	08:00	16:00	#44 **Surgical skill analysis based on the way of grasping organs with forceps in dissection procedure of laparoscopic surgery** Koki Ebina, Takashige Abe, Shunsuke Komizunai, Teppei Tsujita, Kazuya Sase, Xiaoshuai Chen, Madoka Higuchi, Jun Furumido, Naoya Iwahara, Yo Kurashima, Nobuo Shinohara and Atsushi Konno
03:20	08:20	16:20	#90 **A Suspended Cable-Driven Parallel Robot for Human-Cooperative Object Transportation** Yusuke Sugahara, Guangcan Chen, Nanato Atsumi, Daisuke Matsuura, Yukio Takeda, Ryo Mizutani and Ryuta Katamura
03:40	08:40	16:40	#32 **A wheeled vehicle driven by a Savonius–Magnus wind turbine** Marat Dosaev, Liubov Klimina, Margarita Ishkhanyan, Yury Selyutskiy and Anna Masterova
04:00	09:00	17:00	#107 **Determination of the geometric parameters of a parallel-serial rehabilitation robot based on clinical data** Dmitry Malyshev, Lusine Virabyan, Larisa Rybak and Anna Nozdracheva
04:20	09:20	17:20	#104 **Design and Analysis of Cable-Driven Parallel Robot CaRISA: a Cable Robot for Inspecting and Scanning Artwork** Philipp Tempel, Matthias Alfeld and Volkert van der Wijk

Technical Session 7 (Chair: Victor Glazunov and Vigen Arakelian)

NYC	LON	TYO	
04:50	09:50	17:50	#75 **Forward Kinematic Analysis of a Rotary Hexapod** Alexey Fomin, Anton Antonov and Victor Glazunov
05:10	10:10	18:10	#43 **An Approach to motion task-oriented, computer-aided Design of origami-inspired Mechanisms and Robots** Judith U. Merz, Felix J. Reimer, Mathias Huesing and Burkhard Corves

05:30	10:30	18:30	#81 **Automatic planning of psychologically less-stressful trajectories in collaborative workstations: an integrated toolbox for unskilled users** Rafael Rojas, Manuel Ruiz Garcia, Luca Gualtieri, Erwin Rauch and Renato Vidoni
05:50	10:50	18:50	#95 **Experimental study regarding needle deflection in robotic assisted brachytherapy of hepatocellular carcinoma** Paul Tucan, Nicolae Plitea, Bogdan Gherman, Nadim Al Hajjar, Corina Radu, Calin Vaida and Doina Pisla
06:10	11:10	19:10	#63 **Kinematic design of adjustable foot motion generator for gait rehabilitation** Chanatip Thongsookmark, Agnes Beckermann, Mathias Huesing and Yukio Takeda
06:30	11:30	19:30	#91 **Balancing of Planar 5R Symmetrical Parallel Manipulators taking into account the varying payload** Vigen Arakelian and Jing Geng

Industry Session 2

NYC	LON	TYO	
07:00	12:00	20:00	Hitachi, Ltd. The KAITEKI Institute, Inc. JTEKT Corporation

Technical Session 8 (Chair: Giuseppe Quaglia and Burkhard Corves)

NYC	LON	TYO	
07:30	12:30	20:30	#40 **Design and Testing of BIT Flying Robot** Marco Ceccarelli, Yunqi Liu, Hui Li, Qiang Huang, Xiang Wang and Long Li
07:50	12:50	20:50	#46 **Asymmetric Spatial Beams with Symmetric Kinetostatic Behaviour** Ali Amoozandeh Nobaveh, Giuseppe Radaelli and Just Herder
08:10	13:10	21:10	#58 **Design of the mobile robot Agri.q** Paride Cavallone, Luca Carbonari, Giuseppe Quaglia, Carmen Visconte and Andrea Botta
08:30	13:30	21:30	#45 **Stiffness Optimization of Delta Robots** Christian Mirz, Uzsynski Olaf, Jorge Angeles, Yukio Takeda and Burkhard Corves

Keynote Speech 3 (Chair: Gentiane Venture)

NYC	LON	TYO	
09:00	14:00	22:00	**Towards cognition enabled assistive robots** Prof. Dongheui Lee (Technical University of Munich, German Aerospace Center (DLR))

DAY 4 : Thursday 24 September 2020

Technical Session 9 (Chair: Wataru Takano and Hiroyuki Ishii)

NYC	LON	TYO	
00:30	05:30	13:30	#108 **Autonomous Flight of a Quad Tilt-rotor UAV at Constant Altitude** Satoko Abiko and Tomohiro Harada
00:50	05:50	13:50	#70 **Development of a Remote-Controlled Drone System by Using Only Eye Movements for Bedridden Patients** Atsunori Kogawa, Moeko Onda, Yoshihiro Kai, Tetsuya Tanioka, Yuko Yasuhara and Hirokazu Ito
01:10	06:10	14:10	#80 **A mobile robot which locomotes on walls to interact with rodents** Soichi Yamada, Keitaro Ishibashi, Hiroya Yokoyama, Jiei Yanagi, Atsuo Takanishi and Hiroyuki Ishii
01:30	06:30	14:30	#67 **Analysis of Running Expansion with Trunk and Pelvic Rotation Assist Suit by using SLIP model** Hongyuan Ren, Takayuki Tanaka, Kotaro Hashimoto and Akihiko Murai

Technical Session 10 (Chair: Kenji HASHIMOTO and Eiichiro Tanaka)

NYC	LON	TYO	
02:00	07:00	15:00	#66 **Mechanism and Control of Powered Prosthesis with Bi-articular Muscle-type Hydraulic Bilateral Servo Actuator** Takanori Higashihara, Toru Oshima, Takumi Tamamoto, Kengo Ohnishi, Ken'Ichi Koyanagi and Yukio Saito
02:20	07:20	15:20	#76 **Motion Trajectory Optimization of an Assistive Device During Stairs Ascending** Bo-Rong Yang, Shuai-Hong Yu, Kai Pang, Hee-Hyol Lee and Eiichiro Tanaka
02:40	07:40	15:40	#52 **Developing a Flexible Segment Unit for Redundant-DOF Manipulator using Bending Type Pneumatic Artificial Muscle** Hiroki Tomori, Tomohiro Koyama, Hiromitsu Nishikata, Akinori Hayasaka and Ikumi Suzuki
03:00	08:00	16:00	#79 **Kineto-static Analysis of a Compact Wrist Rehabilitation Robot Including the Effect of Human Soft Tissue to Compensate for Joint Misalignment** Ying-Chi Liu and Yukio Takeda
03:20	08:20	16:20	#61 **Active visualization of non-destructive inspection for metal using terahertz camera and light source** Shunsuke Yamada, Teppei Tsujita, Masahiro Kurosaki, Tetsuo Tomizawa, Yutaka Sakuma and Ryosuke Eto

Keynote Speech 4 (Chair: Atsushi Konno)

NYC	LON	TYO	
04:00	09:00	17:00	**Smart fisheries in Japan, toward the sustainable fisheries** Prof. Masaaki Wada (Future University Hakodate)

Technical Session 11 (Chair: Qiang Huang and Yoshihiko Nakamura)

NYC	LON	TYO	
05:10	10:10	18:10	#30 **Continuous Jumping Control Based on Virtual Model Control for a One-leg Robot Platform** Libo Meng, Marco Ceccarelli, Zhuangguo Yu, Xuechao Chen, Gao Huang and Qiang Huang
05:30	10:30	18:30	#38 **Minimizing the Energy Consumption of a Delta Robot by Exploiting the Natural Dynamics** Rafael Balderas Hill, Sébastien Briot, Abdelhamid Chriette and Philippe Martinet
05:50	10:50	18:50	#42 **Sensitivity Analysis of Cable Actuations for Moving a Tensegrity Mechanism along a Specified Path** P. K. Malik, Keshab Patra and Anirban Guha

06:10	11:10	19:10	#51 **Walking Robot Leg Design Based on Translatory Straight-Line Generator** Sayat Ibrayev, Nutpulla Jamalov, Amandyk Tuleshov, Assylbek Jomartov, Aziz Kamal, Aidos Ibrayev and Arman Ibrayeva
06:30	11:30	19:30	#53 **Dynamics of Tendon Actuated Continuum Robots by Cosserat Rod Theory** Arati Bhattu and Salil Kulkarni

Technical Session 12 (Chair: Vincenzo Parenti-Castelli and Mathias Huesing)

NYC	LON	TYO	
07:00	12:00	20:00	#60 **A Decentralized Structure for the Digital Shadows of Internet of Production** Amir Shahidi, Mathias Huesing and Burkhard Corves
07:20	12:20	20:20	#97 **Experimental Study of Force Transmission in 4-DOF Parallel Manipulator and its Educational Applications** Pavel Laryushkin, Elizaveta Pukhova and Ksenia Erastova
07:40	12:40	20:40	#35 **Dynamic Model of Servo Mechanical Press** Assylbek Jomartov, Amandyk Tuleshov, Nutpulla Jamalov, Askar Seidakhmet, Sayat Ibrayev, Moldyr Kuatova and Ablay Kaimov
08:00	13:00	21:00	#109 **Optimal Selection of Transmission Ratio and Stiffness for Series-Elastic Actuators with Known Output Load Torque and Motion Trajectories** Guido Bocchieri, Luca Luzi, Nicola Pedrocchi, Vincenzo Parenti-Castelli and Rocco Vertechy
08:20	13:20	21:20	#74 **A Low Cost Introductory Platform for Advanced Robotic Control** Bin Wei
08:40	13:40	21:40	#78 **Kinematics of 2-DOF AGVs with Differential Driving Wheels and Caster Wheels Modeling** Mohammadreza Montazerijouybari, Luc Baron and Sousso Kelouwani

09:20	16:20	22:20	**Award Ceremony**
09:40	16:40	22:40	**Closing Session**

Previous Symposia

Conceived in the early seventies by Academician I.I. Artobolevskij and Prof. L. Sobrero, the founder of CISM, the symposia have been held since 1973.

Ro.Man.Sy. '73, Udine (Italy)
Chairperson: A.E. Kobrinskij
45 papers, 65 participants from 11 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy '76, Jadwisin (Poland)
Chairperson: B. Roth
47 papers, 13 films, 117 participants from 20 countries
Proceedings distributed by Elsevier, Scientific Publishing Company (Amsterdam) and PWN (Warsaw)

Ro.Man.Sy. '78, Udine (Italy)
Chairperson: L. Sobrero
48 papers, 15 films, 67 participants from 12 countries
Proceedings distributed by Elsevier, Scientific Publishing Company (Amsterdam) and PWN (Warsaw)

Ro.Man.Sy. '81, Zaborów (Poland)
Chairperson: A. Morecki
37 papers, 15 films, 73 participants from 16 countries
Proceedings distributed by PWN (Warsaw)

Ro.Man.Sy. '84, Udine (Italy)
Chairperson: G. Bianchi
45 papers, 10 films, 65 participants from 14 countries
Proceedings distributed by Hermés (Paris), Kogan-Page (London) and MIT Press (Cambridge, USA)

Ro.Man.Sy. '86, Cracow (Poland)
Chairperson: A. Morecki
66 papers, 14 films, 90 participants from 15 countries
Proceedings distributed by Hermes (Paris), Kogan-Page (London) and MIT Press (Cambridge, USA)

Ro.Man.Sy. '88, Udine (Italy)
Chairperson: G. Bianchi and A. Morecki
61 papers, 71 participants from 15 countries
Proceedings distributed by Hermes (Paris)

Ro.Man.Sy. '90, Cracow (Poland)
Chairperson: A. Morecki and G. Bianchi
55 papers, 93 participants from 16 countries
Proceedings distributed by CISM (Udine) and Warsaw University of Technology (Warsaw)

Ro.Man.Sy. '92, Udine (Italy)
Chairperson: G. Bianchi and A. Morecki
40 papers, 4 videos, 50 participants from 14 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. '94, Gdansk (Poland)
Chairperson: A. Morecki and G. Bianchi
52 papers, 64 participants from 17 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. '96, Udine (Italy)
Chairperson: G. Bianchi and A. Morecki
45 papers, 5 videos, 59 participants from 13 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. '98, Paris (France)
Chairperson: G. Bianchi and A. Morecki, Local Chairperson: J.-C. Guinot
50 papers, 40 videos, 102 participants from 14 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. 2000, Zakopane (Poland)
Chairperson: A. Morecki and G. Bianchi
52 papers, 74 participants from 15 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. 2002, Udine (Italy)
Chairperson: G. Bianchi and J.-C. Guinot
3 keynote lectures, 54 papers, 62 participants from 21 countries
Proceedings distributed Springer Verlag (Vienna)

Ro.Man.Sy. 2004, Saint-Hubert (Canada)
Chairperson: J. Angeles and J.-C. Piedboeuf
4 keynote lectures, 37 papers, 55 participants from 13 countries

Ro.Man.Sy. 2006, Warsaw (Poland)
Chairperson: T. Zielinska
3 keynote lectures, 50 papers, 70 participants from 17 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. 2008, Tokyo (Japan)
Chairperson: A. Takanishi

3 keynote lectures, 70 papers, 93 participants from 16 countries
Proceedings distributed by Kamiya Printing (Tokyo)

Ro.Man.Sy. 2010, Udine (Italy)
Chairperson: V. Parenti Castelli and W.O. Schiehlen
3 keynote lectures, 56 papers, 72 participants from 22 countries
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. 2012, Paris (France)
Chairperson: Ph. Bidaud and O. Khatib
Proceedings distributed by Springer Verlag (Vienna)

Ro.Man.Sy. 2014, Moscow (Russia)
Chairperson: M. Ceccarelli and V. Glazunov
Proceedings distributed by Springer International

Ro.Man.Sy. 2016, Udine (Italy)
Chairperson: V. Parenti Castelli and W. Schiehlen
Proceedings distributed by Springer International

Ro.Man.Sy. 2018, Rennes (France)
Chairperson: V. Arakelyan and P. Wenger
Proceedings distributed by Springer International


「あしたは」は、ナニイロ？
鹿島のしごと。
それは「あした」をつくること。
人と自然と向き合って、
よりよい毎日をつないでいくこと。
暮らしを描く、ものづくり。
無限の創造力で、彩り豊かな未来へ。
100年をつくる会社
鹿島

SOLUTIONS

鹿島スマート生産

KAJIMA SMART FUTURE

ENGINEERING

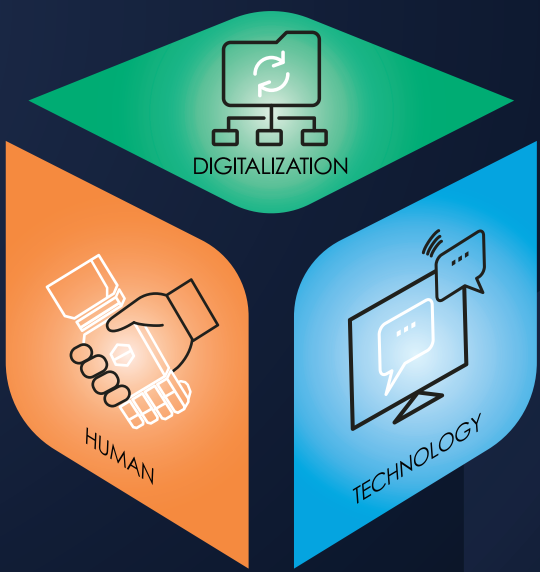
全てのプロセスをデジタルに

WORK

作業の半分はロボットと

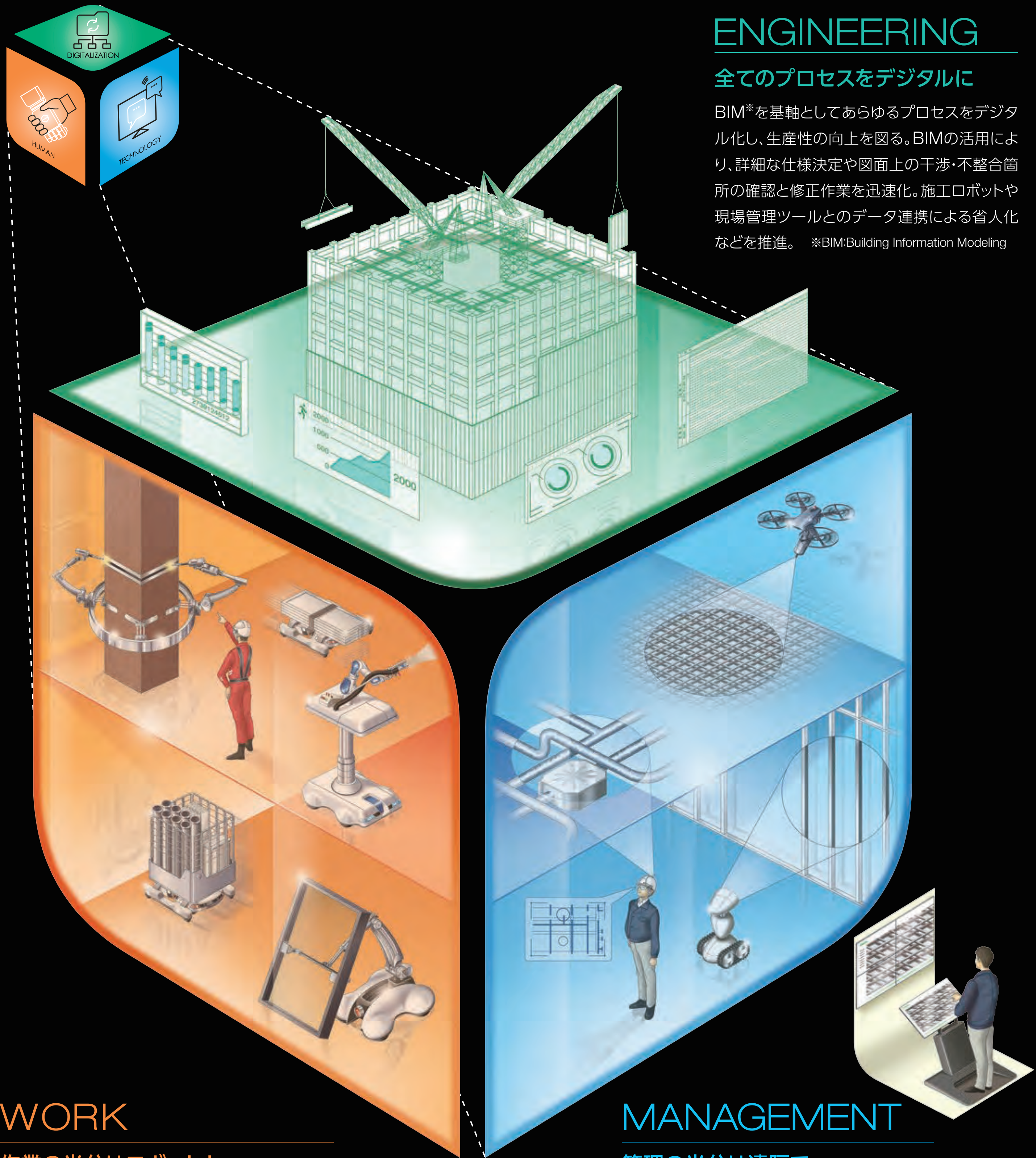
MANAGEMENT

管理の半分は遠隔で



建築の生産プロセスを変革

BIMを基軸とした先端ICTや各種ロボットの活用と現場管理手法の革新により、生産性の向上とより魅力的な建築生産



ENGINEERING

全てのプロセスをデジタルに

BIM※を基軸としてあらゆるプロセスをデジタル化し、生産性の向上を図る。BIMの活用により、詳細な仕様決定や図面上の干渉・不整合箇所の確認と修正作業を迅速化。施工ロボットや現場管理ツールとのデータ連携による省人化などを推進。　※BIM:Building Information Modeling

WORK

作業の半分はロボットと

人と機械（ロボット）の協働による生産性向上を図る。資材運搬などの単純作業や耐火被覆吹付けなどの厳しい環境下での作業は機械化を進める一方、特殊な部材の施工や複雑な調整を必要とする作業は、これまでどおり人が行う。

MANAGEMENT

管理の半分は遠隔で

現物確認と遠隔管理の組み合わせで、現場管理者の働き方改革を図る。作業進捗状況などの単純な確認業務は、工事事務所や現場外からの遠隔管理にシフトするとともに、協力会社など関係者とのリアルタイムな情報共有を推進する。

する「鹿島スマート生産」

プロセスの実現を目指します。

「鹿島スマート生産ビジョン」
コンセプト動画はこちらから

代表的な技術

WORK
人とロボットの協働

»鉄骨溶接ロボット
- 鉄骨接合部の現場溶接を自動化（柱コーナー部含む）
- 柱横向き、梁下向き・上向き・縦向き溶接に対応

»耐火被覆吹付ロボット
- マニピュレータにより鉄骨の形状に沿った吹付けが可能、高所の吹付けにも対応
- BIMと連携し、梁の配管用開口部や補強用プレートなど複雑な形状に対応

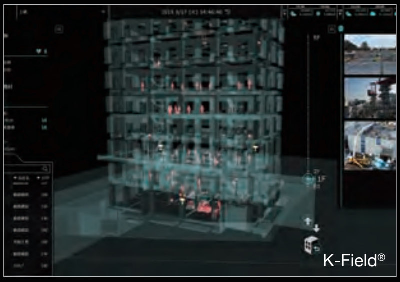
»コンクリート押えロボット
- 床スラブのコンクリート押え作業を自動化
- タブレット入力した作業範囲から走行コースを自動設定。自律走行しながらコンクリート表面を仕上げる

その他
- »ウェアラブルバイブレータ
- »外装取付アシストマシン
- »疲労軽減アシストスーツ

MANAGEMENT
現物確認と遠隔管理の組み合わせ

»現場内モニタリングシステム
- カメラを現場各所に配置して遠隔で状況把握
- 施工管理に必要な各種情報をスマート工事事務所で一元管理

»ドローン自動巡回システム
- 作業終了後や地下ピット内・高所などの巡回点検を遠隔化



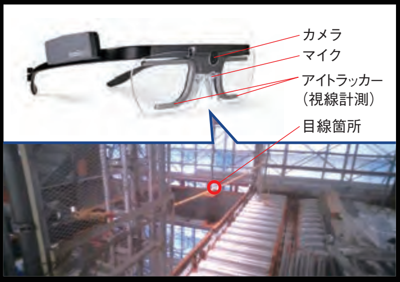
»資機材位置・稼働モニタリング
- 現場内の資機材位置と稼働状況をリアルタイムに表示

その他
- »鉄骨建方精度モニタリング
- »顔認証入退場管理
- »搬送管理システム

ENGINEERING
BIMを基軸とした全プロセスのデジタル化

»BIM/ARチェックシステム
- 目前の現況映像の上にBIMの設計情報から生成したCGを重ね施工後の姿を確認
- タブレット端末で天井内配管を事前確認

»施工計画作成システム
- 仮設資機材の配置ツールと施工計画の支援機能を搭載したARCHICAD専用のアドオンソフトウェア



»技能伝承システム
- ベテランの知見を動画と音声でデータ化、教育に活用
- 現場巡回や製品検査時のチェックポイントを動画（目線箇所付き）と音声で記録

その他
- »BIM/出来形検査連携システム
- »BIM/VR活用
- »BIM/鉄筋加工連携システム

現場紹介 1

パイロット現場として技術やシステムを適用・実証

スマート生産に関連する各種技術・システムを集中的に適用・実証。
技術革新の最先端を体現した現場。

[工事概要]
場　所：名古屋市中区
発注者：鹿島建設
設　計：当社中部支店建築設計部
用　途：事務所、店舗、駐車場
規　模：S・CFT造　13F　延べ16,891m²
工　期：2018年3月～2019年9月
（中部支店施工）

伏見のメインストリート
錦通に面する鹿島伏見ビル

本格導入された鉄骨溶接ロボット

ロボット化技術のひとつである「鉄骨溶接ロボット」を用いて、コア部の柱・柱接合部全周溶接の一部、柱・梁仕口部の下フランジ溶接の全箇所を施工した。あらかじめ入力されたデータとセンサによって、自動で位置や電流を調節。ロボット10台とオペレータ8名により、柱10ヵ所、梁585ヵ所の溶接作業を安全・高品質に完了した。

また、これまでロボットではできなかった角柱の四隅アール（曲線）部の溶接も行った。まず、ロボット2台で同時に2ヵ所の対角を溶接、付け替えてさらに2ヵ所の対角を溶接した後、上側と下側の柱を仮固定していた部品（エレクションピース）を外して直線部を溶接する。現在、柱の全周を付け替えることなく溶接できるロボット開発も進んでいる。

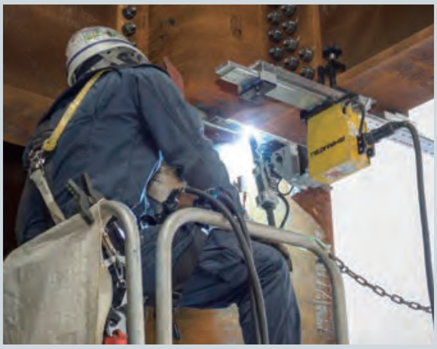
ロボット溶接のうち、今回とくに注目すべきは、人では技術的に困難だった下方からの上向き溶接が可能になったことだ。これまで下フランジを上方から溶接していたため上階の床を後施工していたが、その必要がなくなり、品質・安全の向上に加え、工程の短縮にもつながる。

作業の半分はロボットと協働

外装の取付段階では「外装取付アシストマシン」を実証。1枚200kgもの外装材を取り付けた。外装材をアームで持ち上げ・旋回・移動・取付という動作を操作用コントローラーで操る。これまで4人で行っていた作業を2人一組で行うことが可能となる。

また、始業前点検、現場状況の確認、夜間の点検などにおいて「ドローン自動巡回」の現場実証が行われた。今後、ドローンによる出来形計測とBIMを連携することによる出来形進捗状況の管理なども期待されている。

そのほか、「コンクリート押えロボット」「疲労軽減アシストスーツ」「ウェアラブルバイブレータ」などのロボット化技術や遠隔管理技術、計画・管理技術の現場実証が行われ、将来の実用化に向けた様々なデータ収集が行われた。



梁下フランジの上向溶接

外装取付アシストマシン（マイティフェザー®）は、操縦する人と取付位置の干渉を確認する人の2人で作業を行う

Interview

人がつなぐ技術の革新

スタート当初はロボットがどこまで人の代わりになるか半信半疑でしたが、現場に適用してみるとこれは使える技術だという確信に変わりました。

しかし、まだまだ改良の余地はあります。たとえば、人が行う溶接では、作業員は風が吹いたら自分の体を風除けにするなどの細かな技を身につけています。それらを今後溶接ロボットの自動化に活かせないかなど、現場で使ってみて気づくことが多くありました。

特殊部材の施工や複雑な調整が必要なものは人が行い、品質を確保する必要があります。人はロボットと協働し、生産性を向上させていく。これからの建築工事には、さらにロボットが進出してくるでしょう。そのためにも、現場の人にはロボットに対するアイデアや要望をどんどん出していってほしい。それが技術の革新につながっていくと考えます。

中部支店　鹿島伏見ビル工事事務所
木村 友昭 所長

現場紹介 2

BIM導入による プロセスのデジタル化

生産性向上のため、設計・施工から建物の維持管理までBIMを活用。
さらに一歩進んだ安全管理、品質管理へと広がる可能性をカタチにする。

［工事概要］
場　所：大阪市中央区
発注者：オービック
設　計：当社関西支店建築設計部
用　途：店舗、事務所、ホテル、駐車場、ホール（集会場）
規　模：S・SRC・RC造（制震構造）　B2、25F
延べ55,527m^2
工　期：2017年5月～2020年1月（予定）
（関西支店施工）

完成後は御堂筋最大級の
ランドマークとなる
オービック御堂筋ビル

データの一元管理で生産性を向上

BIMは、建物の3Dモデルとデータベースを融合させたシステム。企画から設計、施工、建物管理に至る情報を一元管理し、目的に応じて様々なデータを抽出・活用する。各フェーズでデータを重複して作成する必要がないため、生産性の向上を図ることができる。さらに、発注者や設計者、施工者といった多くの関係者間でリアルタイムに情報共有することができるため、プロジェクトを一体的に推進するコミュニケーションツールとしても活躍する。

基本設計から実施設計でBIM活用

意匠・構造・設備の各基本設計段階においては、ひとつのモデルを共有することで、設計図面などの整合性検証がスムーズに行えることを目指した。
実施設計段階では、屋上から地下までほぼすべてのフロアをBIMモデル化し、実施設計図に落とし込んだ。たとえば、オフィスフロアにおいてはBIMの数量拾い機能を用いて、経済的な基本モジュールの決定やメンテナンススペースを確保した納まりの検討など、通常では施工図レベルで行うような検討を重ねていった。また、BIMにより、各種設備機器や操作スイッチなどのすべてに属性情報を付加した総合プロット図を作成、画面上での仕様の確認を可能とした。上層階のホテルエリアでは、BIMモデルによる客室用配管ユニットのバーチャルモックアップを作成、メンテナンス性や将来更新スペースの確認を行うことで顧客とのスムーズな合意形成が可能となった。

エントランス意匠確認用VRで映り込みなどを確認

ホロレンズを用いた天井内の配管チェック

VR活用や気流シミュレーションにも

施工段階では、施工図チェック、意匠確認、工事進捗の見える化、シミュレーションによる性能評価などにもBIMが使われた。
たとえば、現場で採用する製品決定のプロセスにおいては、エントランス意匠のVR※活用により、取り付けるライトの光度の変化や光の映り込みなどを、ホロレンズ（ヘッドマウントディスプレイ）を着用して確認。また、最適な制気口やダクト位置の納まり検討にはBIMモデルを用いた気流シミュレーションを行った。

※ VR…Virtual Reality

Interview

BIM は建物すべてのデータベース

この現場では、様々なフェーズでBIMを活用し、社内外から大きな反響をいただいています。
特徴的な点としては、まず現場加工で出るゴミがかなり少ない。これはBIMにより着工前に設備設計を徹底的に行い、プレファブ化（あらかじめ工場で部材を組み立てること）し、ユニット化して検査まで完了させてから搬入、現場では可能な限り取付けのみの作業としたことで、とてもクリーンな環境となったからです。BIM導入による効果は、設計施工ばかりでなく、建物完成後の維持管理においても現れてくるはずです。たとえば、主要な設備機器には二次元コードを付けています。これにより、メンテナンス時期や異常時の機器コードなどが確認でき、維持管理が容易になります。これからも社員や協力会社の方々へのBIM普及に努めていきたいと思います。

関西支店　オービック御堂筋工事事務所
北村　浩一郎 所長

Introduction of Hitachi's R&D 【Part1】 Logistics Automation

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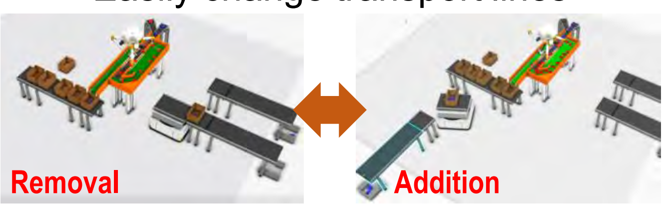
1. Our concept

We aim to realize
"changeable automation system"
which can flexibly adapt to the following changes and evolutions:
- consumer needs
- customer (logistics company) situations
- machines and technologies.

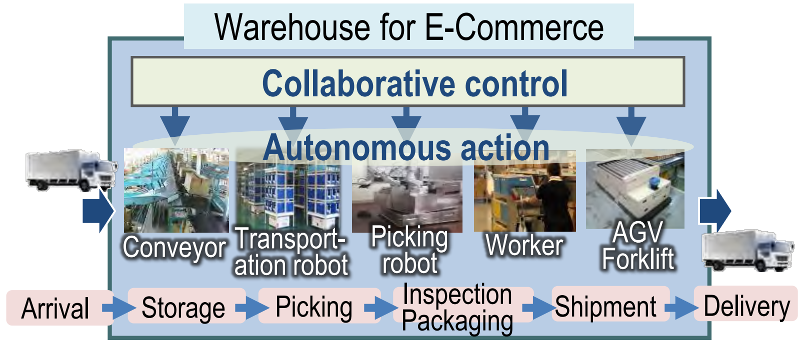
Needs of change

a) Kinds of Items
-> Easily register new items

b) Amount of items
-> Easily change transport lines



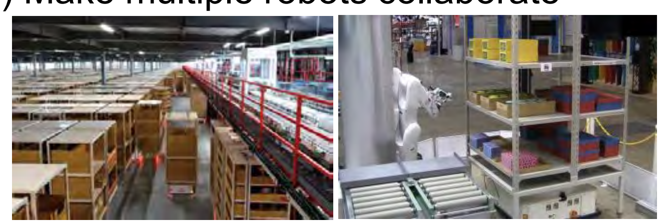
We are developing robotics technologies to make machines
"autonomous and collaborate"
for enhancing both efficiency and flexibility of logistics automation system[1].



Developed robotics technologies

A) Make each robot autonomous

B) Make multiple robots collaborate

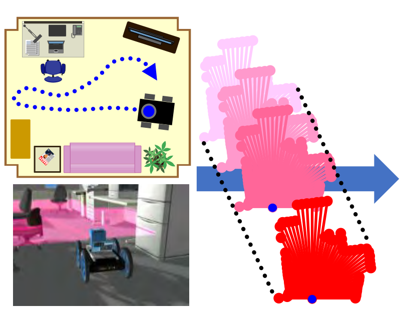


[1] T. Moriya et al., "Development of Autonomous and Collaborative Robotics Technologies for Advanced Automation," Hitachi Review, Vol. 68, No. 4, pp. 520-525, 2019.

2. Autonomous control technologies

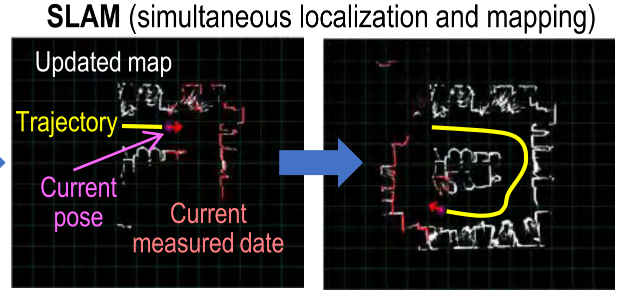
2.1 Autonomous locomotion

The following functions are realized with **SLAM techniques**[2,3]:
- self-localization
- map building
- locomotion along route
- obstacle detection and avoidance.



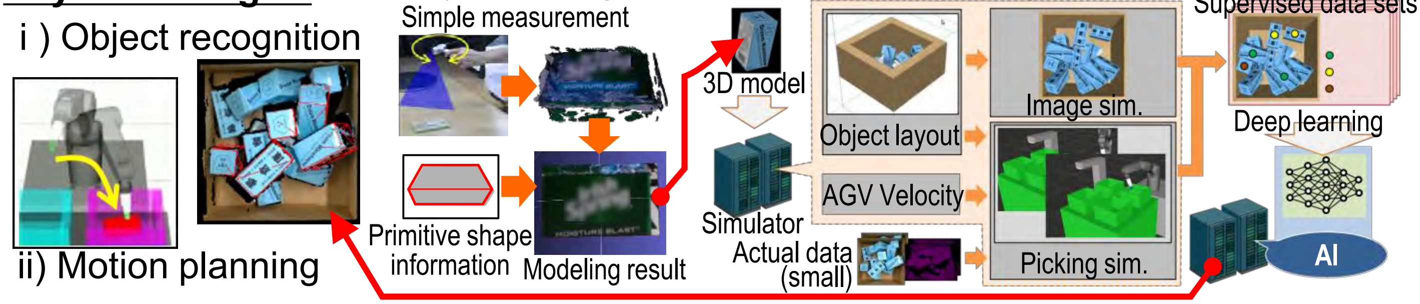
Measurement with range finder

SLAM (simultaneous localization and mapping)



2.2 Autonomous object manipulation

Key technologies

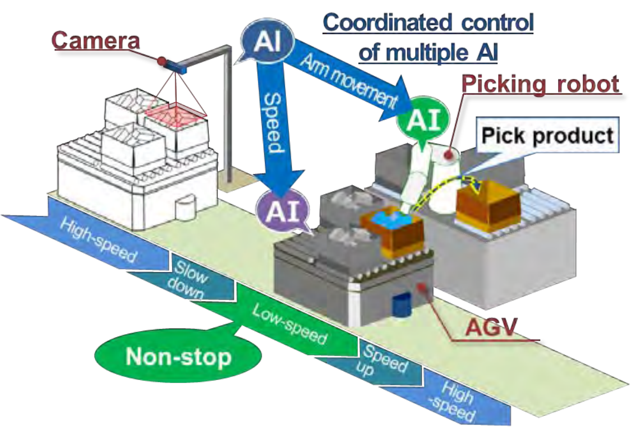


[2] J. J. Leonard and H. F. Durrant-Whyte, "Simultaneous Map Building and Localization for an Autonomous Mobile Robot," Proc. of IEEE/RSJ Int. Workshop on Intelligent Robots and Systems, Vol. 3, pp. 1442-1447. 1991.
[3] N. Kimura et al, "Real-Time Updating of 2D Map for Autonomous Robot Locomotion Based on Distinction Between Static and Semi-Static Objects," Advanced Robotics, Vol. 26, Issue 11-12, pp. 1343-1368, 2012.

3. Collaborative control technologies

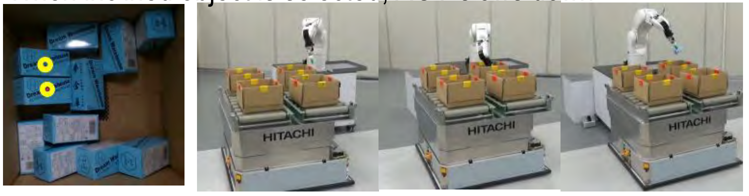
3.1 Collaboration between manipulator & AGV

Supervisor AI simultaneously determines target object to be picked up and transport velocity depending on layout of objects, and AI sends these information to manipulator and AGV. Manipulator can pick up target object without AGV pausing [4].



When object laying down is selected, AGV keeps its velocity.

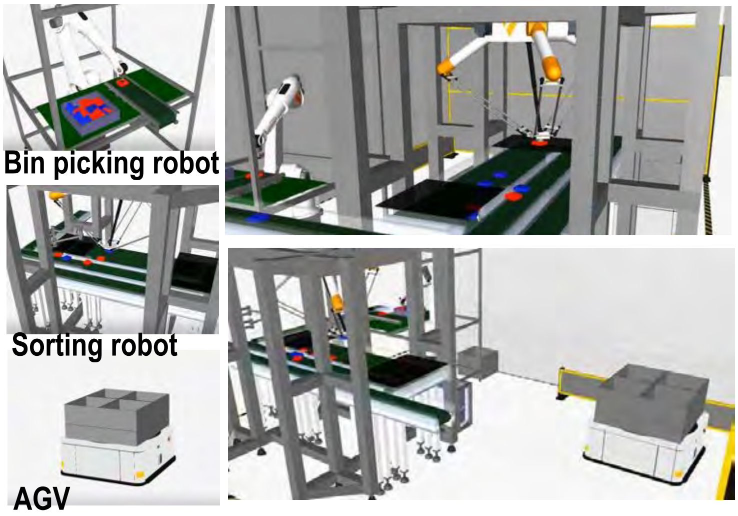
When inclined object is selected, AGV slows down.



3.2 Simulation

Our simulation technology can be used for
- design of robot system with multiple subsystems
- preliminary check of physical consistency between subsystems.

Without actual preliminary check, we successfully established actual demonstration system with 3 subsystems developed in each different laboratory / factory.

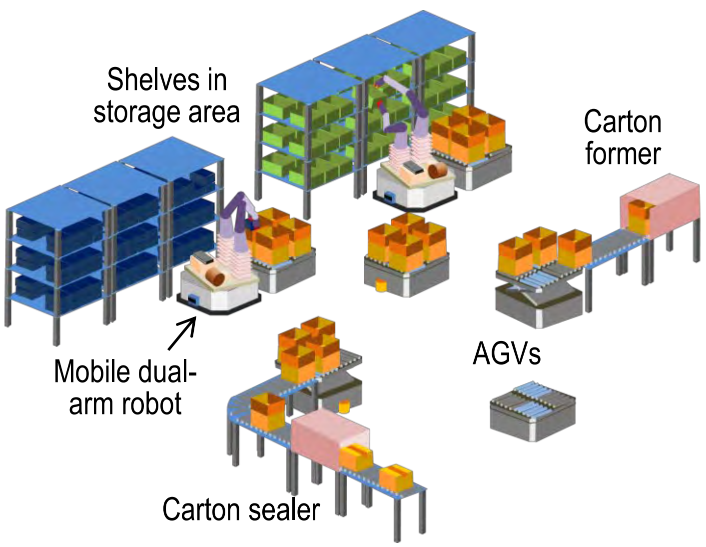


[4] N. Kimura et al., "Simultaneously Determining Target Object and Transport Velocity for Manipulator and Moving Vehicle in Piece-Picking Operation," Proc. of 2019 IEEE Int. Conf. on Automation Science, pp. 1066-1073, 2019.

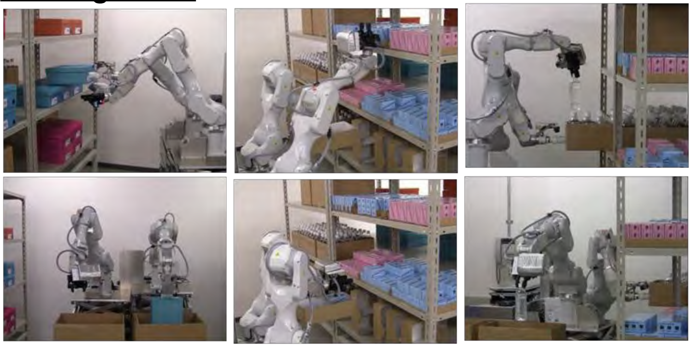
4. Prototypes of automated order picking system

4.1 Mobile dual-arm robot

This kind of robots can move around warehouse and pick / stock various kinds of items from/onto shelves [5-7]. In one of our prototyped systems, AGVs are also used for transporting some cases.



Picking tasks



Stocking tasks

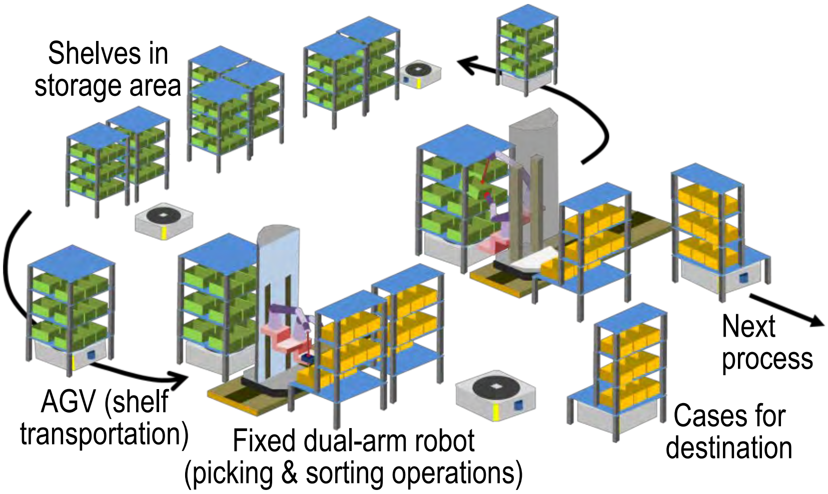
4.2 Collaboration between AGV & fixed dual-arm robot

We also tried to clearly assign roles to machines as follows:

movement -> AGV
object handling -> fixed dual-arm robot.

We confirmed this robot system can successfully perform actual order picking operation.

AGV and fixed dual-arm robot



Recognize items with RGBD camera

Keep items on small table

Place items densely

[5] N. Kimura et al., "Mobile Dual-Arm Robot for Automated Order Picking System in Warehouse Containing Various Kinds of Products," Proc. of 2015 IEEE/SICE Int. Sym. on System Integration, pp. 332-338, 2015.
[6] T. Fuji et al., "Architecture for Recognizing Stacked Box Objects for Automated Warehousing Robot System," Proc. of the 17th Irish Machine Vision and Image Processing conf., pp. 51-58, 2015.
[7] R. Sakai et al, "A Mobile Dual-Arm Manipulation Robot System for Stocking and Disposing of Items in a Convenience Store by Using Universal Vacuum Grippers for Grasping Items," Advanced Robotics, Vol. 34, Issue 3-4, pp. 219-234, 2019.

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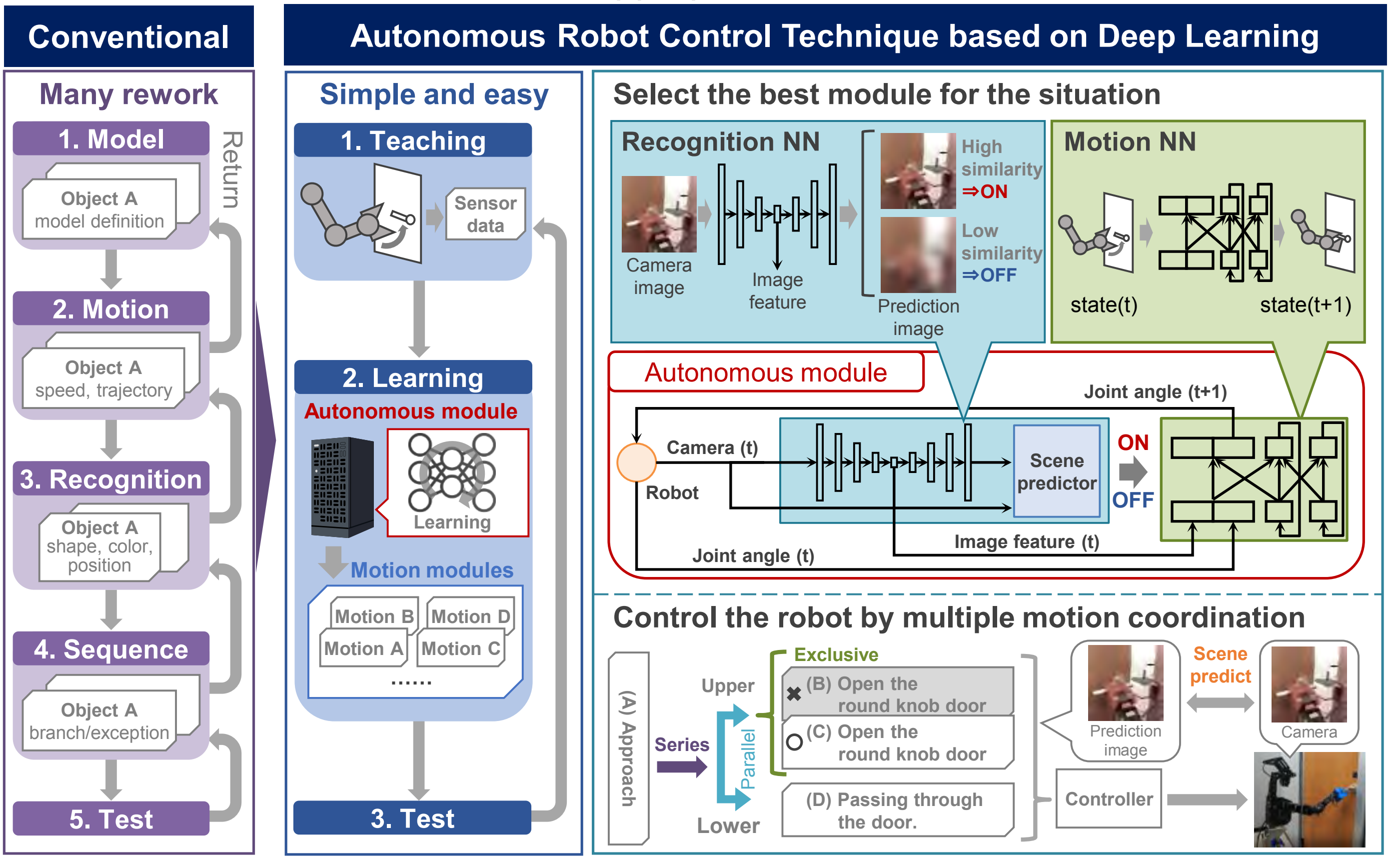
1. Deep Learning Technology to Control a Robot for Autonomously Combining Multiple Motions

Our developed main technologies[1-2] are below:

- Deep learning technology that acquire complex autonomous motions in autonomous modules with simple teaching steps such as a remote-operation that eliminates the large amounts of programming work.
- Situation recognition technology that determines similarity with acquired learning experience and autonomously performs appropriate actions according to the situation.
- Sequence control technology that generates complex motions by combining multiple learned autonomous motions at a appropriate time.

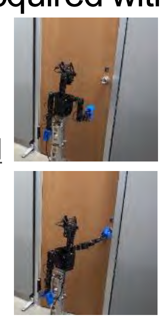


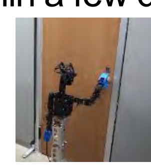
To test the technologies, we demonstrated the ability to open and pass through many type doors (below), that involves many motions working together that acquired within a few day.

Pushing the door

Pulling the door

Round knob





Check here for details

http://www.hitachi.co.jp/rd/sc/video/2019/1902b.html

[1] Hiroshi Ito, Kenjiro Yamamoto and Tetsuya Ogata: Development of Integration Method of Element Motions using Deep Learning, No. 18-2 Proc. of the 2018 JSME Conference on Robotics and Mechatronics, Kitakyushu, Japan, June 2-5, 2018 [ROBOMECH AWORD]

[2] Hiroshi Ito, Kenjiro Yamamoto, Hiroki Mori, and Tetsuya Ogata: Evaluation of Generalization Performance of Visuo-Motor Learning by Analyzing Internal State Structured from Robot Motion, New Generation Computing, vol. 38, pp.7-22, Jan. 2020.

※ This research is the result of joint research with the Tetsuya Ogata Laboratory, Waseda University.

あたらしい動きをつくる。

人とロボットの協働を“足元”から支える
ダイレクトドライブ車輪ユニット

※本製品はNSKが提案するコンセプトモデルです。

摩擦にも“働き方改革”

現在、私たちの社会で進められている「働き方改革」。この改革により、ニーズに応じた働き方の選択肢が増え、多くの人が意欲をもって働くことができる環境づくりが推進されています。また、この改革が進むことが、働く場所やスタイル、家庭や育児との両立のさせ方、何を大切にして働くべきか?など、働く意義や権利を考えるきっかけになっています。
NSKは2016年に創立100周年を迎えた、ベアリングなど精密な機械部品を開発・製造するメーカー。NSKの製品は、世の中のあらゆる動くモノに組み込まれ、モノとモノの間に生まれる“摩擦の働き方”に「改革」を起こし続けることで、世界の人々の暮らしや産業を100年以上支えてきました。

私たちはそんな摩擦の働き方改革を、移動型ロボットにも起こそうとしています。これまでの移動型ロボットは、工場などでモノを大量に運搬することが主な業務でした。この移動型ロボットが進化し、もっと人のそばで作業ができたり、人の手助けをしてくれたなら、私たちの“働き方”は大きく変わるはず。そんな発想から誕生したのが、ロボットの駆動部分を担うNSKの新技術『ダイレクトドライブ車輪ユニット』です。
車輪の駆動部の“摩擦の働き方”に着目した『ダイレクトドライブ車輪ユニット』は、静かで滑らかに動いたり、呼ばれたら素早く駆け寄ってきたり、ぶつかりそうなときには道を譲ったりするなど、人の暮らしや働き方に寄り添うために、働く人の声を取り入れながら新しい技術や機能の開発を進めています。
NSKが起こす“摩擦の働き方改革”は、人の働き方改革も加速させると信じています。そして100周年ビジョン「あたらしい動きをつくる。」のもと、人の働き方だけでなく、様々な角度から社会課題の解決を目指し、世界に先駆けた“動き”をつくることがNSKの使命です。グローバル社会のサステナブルな発展のために、NSKの挑戦に終わりはありません。

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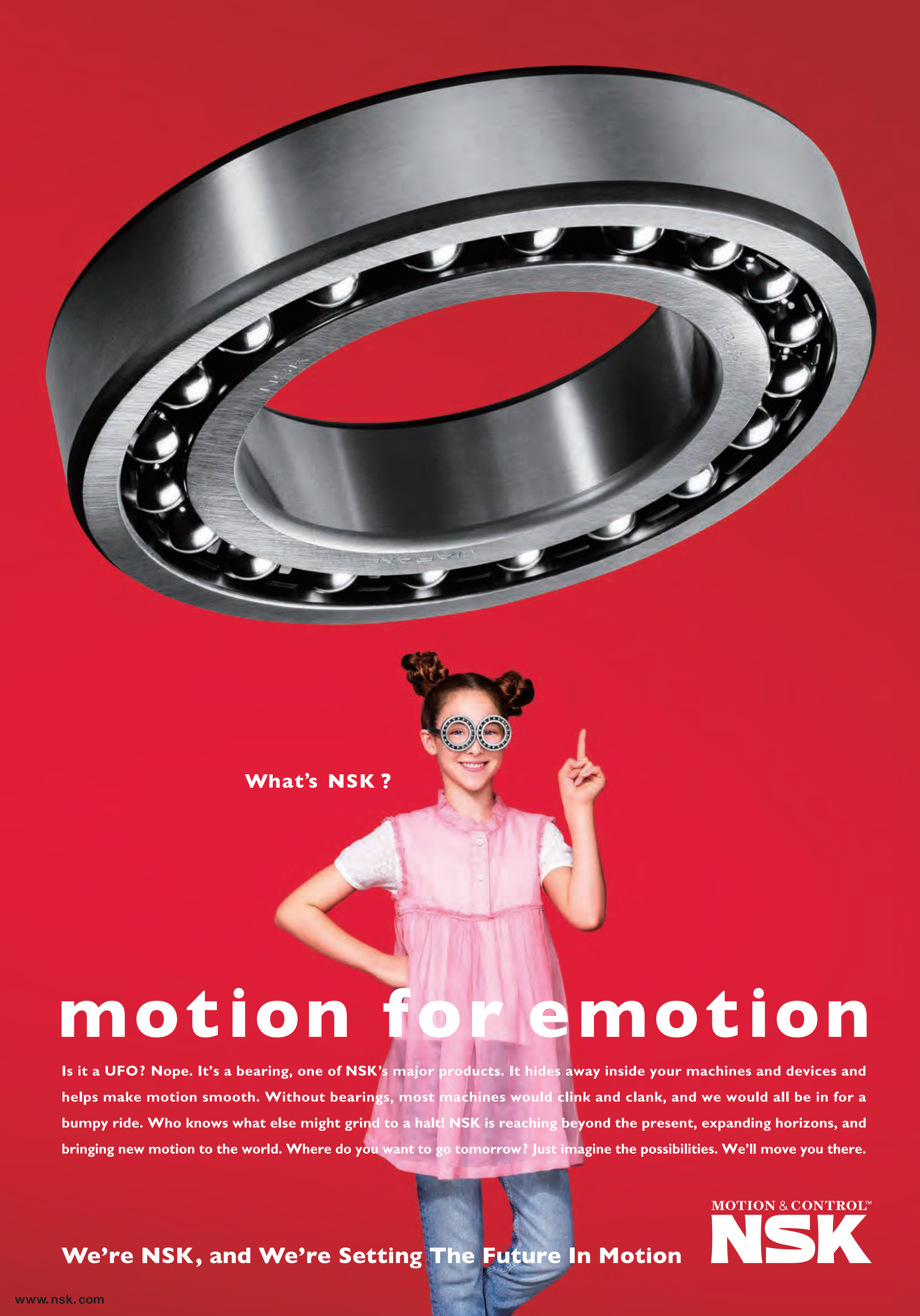
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