



# CLAWAR

30 Aug - 1 Sep 2021



TAKARAZUKA, JAPAN

## Technical Program



関西学院大学

KWANSEI GAKUIN UNIVERSITY

# Welcome to CLAWAR 2021

It is our pleasure to welcome you all to the CLAWAR2021 conference, held virtually in Takarazuka, Japan during 30 August – 01 September 2021. CLAWAR2021 is the 24<sup>th</sup> edition of the International Conference series on Climbing and Walking Robots and the Support Technologies for Mobile Machines. The technical programme of the conference includes three keynote presentations, given by well-known scientists in their fields of research, and 42 original articles with cutting-edge scientific findings in a wide range of topics related to the rapidly evolving areas of robotics. We hope that CLAWAR2021 will enable delegates to exchange research ideas and to establish collaborative networks for advancement of science and knowledge discovery in the field of robotics and associated technologies, for a sustainable future.

The CLAWAR2021 proceedings are published by Springer in their book series in “Lecture Notes in Networks and Systems”, which is indexed in Web of Science, dblp, and SCOPUS. It is believed that this book will serve as a source of inspiration and further innovation in research and development in the rapidly growing area of mobile service robotics.

We would like to thank members of the International Scientific Committee and National Organising Committee of CLAWAR 2021 for their efforts in reviewing the submitted articles, and for their support in the planning and organisation of the conference.

Daisuke Chugo, M. Osman Tokhi & Sho Yokota  
General Co-Chairs, CLAWAR2021

# CLAWAR 2021 Conference Organization

## General Co-Chairs

Daisuke Chugo, Kwansei Gakuin University, Japan  
M. Osman Tokhi, London South Bank University, United Kingdom  
Sho Yokota, Toyo University, Japan

## International Scientific Committee Co-Chairs

Taro Nakamura, Chuo University, Japan  
Manuel F. Silva, ISEP & INESC TEC, Portugal  
Manabu Okui, Chuo University, Japan

## International Advisory Committee Chair

Gurvinder S. Virk, CLAWAR Association, United Kingdom

## National Organizing Committee Chair

Hiroyuki Kobayashi, Osaka Institute of Technology, Japan

## Publications Co-Chairs

Daisuke Chugo, Kwansei Gakuin University, Japan  
M. Osman Tokhi, London South Bank University, United Kingdom

## Special/Workshop Sessions Chair

Khaled M. Goher, University of Lincoln, United Kingdom

## Local Arrangements Chair

Hiroyuki Kobayashi, Osaka Institute of Technology, Japan

## Publicity Co-Chairs

Abdullah Almeshal, College of technological studies, Kuwait  
Masayoshi Wada, Tokyo University of Science, Japan

## Web-site Chair

Abdullah Almeshal, College of technological studies, Kuwait

## International Scientific Committee

Ahmad, S.	– Malaysia	Farias, P.	– Brazil
Almeshal, A.	– Kuwait	Fernandez, R.	– Spain
Armada, M.	– Spain	Ferreira, P.	– Portugal
Banfield, I.	– Panama	Friebe, A.	– Sweden
Belter, D.	– Poland	Gallegos Garrido, G.	– UK
Berns, K.	– Germany	Garcia, D.	– Panama
Bidaud, Ph.	– France	Grand, C.	– France
Bonsignorio, F.	– Italy	Guedes, P.	– Portugal
Bridge, B.	– UK	Hassan, M. K.	– Malaysia
Briskin, E.	– Russia	Hwang, K.-S.	– Taiwan
Burlacu, A.	– Romania	Ion, I.	– Romania
Chevallereau, C.	– France	Kaur, A. P.	– UK
Chrysostomou, D.	– Denmark	Kiriazov, P.	– Bulgaria
Costa, M. T.	– Portugal	Kobayashi, H.	– Japan
Dehghani-Sanij, A.	– UK	Kozłowski, K.	– Poland
Dias, A.	– Portugal	Leon-Rodriguez, H.	– Colombia
Dillmann, R.	– Germany	Marques, L.	– Portugal
El Youssef E. S.	– Brazil	Martins, D.	– Brazil
Ermolov I.	– Russia	Mejja Rincon, L.	– Brazil
Faina, A.	– Denmark	Mohamed, Z.	– Malaysia

Molfino, R.	– Italy	Rodríguez Lera, F. J.	– France
Monje, C. A.	– Spain	Semini, C.	– Italy
Montes, H.	– Panama	Sequeira, J.	– Portugal
Moon, S.	– Korea	Skrzypczynski, P.	– Poland
Muramatsu, S.	– Japan	Su, H.	– China
Muscato, G.	– Italy	Tenreiro Machado, J.	– Portugal
Nunuparov, A.	– Russia	Visser, A.	– The Netherlands
Okui, M.	– Japan	Wada, M.	– Japan
Paraforos, D.	– Germany	Wu, J.	– China
Park, H. S.	– Korea	Xie, M.	– Singapore
Penders, J.	– UK	Yatsun, S.	– Russia
Petry, M.	– Portugal	Yigit, A.	– Kuwait
Plentz, P. D. M.	– Brazil	Yokota, S.	– Japan
Rachkov, M.	– Russia	Zhong, Z. W.	– Singapore
Reina, G.	– Italy	Zhukov, A.	– Russia
Ribeiro, M.	– Portugal	Zielinska, T.	– Poland
Rocha, R. P.	– Portugal		

# CLAWAR 2021 Technical Programme

Monday 30 August 2021

<b>Time: 05:30 – 06:30 (UTC), 14:30 – 15:30 (JST)</b>	
05:30-06:00 14:30-15:00	Conference Registration
06:00-06:30 15:00-15:30	Opening Session

## Session – M1: Modelling and simulation of CLAWAR I Session Chair: José Lima

**Time: 06:30 – 07:30 (UTC), 15:30 – 16:30 (JST)**

Time	Paper ID	Proc Page	Presentation
06:30-06:45 15:30-15:45	#5		CLIMBLAB: MATLAB SIMULATION PLATFORM FOR LEGGED CLIMBING ROBOTICS <i>Kentaro Uno, Warley F. R. Ribeiro, Yusuke Koizumi, Keigo Haji, Koki Kurihara, William Jones and Kazuya Yoshida</i>
06:45-07:00 15:45-16:00	#15		MODELING AND MOTION ANALYSIS OF PLANAR PASSIVE-DYNAMIC WALKER WITH TENSEGRITY STRUCTURE FORMED BY FOUR LIMBS AND EIGHT VISCOELASTIC ELEMENTS <i>Fumihiko Asano, Yanqiu Zheng and Longchuan Li</i>
07:00-07:15 16:00-16:15	#20		TRAJECTORY PLANNING STRATEGY FOR THE LINKS OF A WALKING HUMAN-MACHINE SYSTEM USING A NEURAL NETWORK <i>Sergey Jatsun, Andrei Malchikov, Alexey Postolniiy and Andrey Yatsun</i>
07:15-07:30 16:15-16:30	#28		PASSIVE MOTION ANALYSIS OF TWO IDENTICAL REGULAR OCTAGONAL OBJECTS THAT MOVE ON PASSIVELY VIBRATING TILTED STAGE <i>Fumihiko Asano, Longchuan Li and Isao Tokuda</i>

**Session – M2: Modelling and simulation of CLAWAR II**  
**Session Chair: José Lima**

**Time: 07:45 – 08:45 (UTC), 16:45 – 17:45 (JST)**

Time	Paper ID	Proc Page	Presentation
07:45-08:00 16:45-17:00	#29		ANALYSIS OF PASSIVE DYNAMIC GAIT OF TENSEGRITY ROBOT <i>Yanqiu Zheng, Fumihiko Asano, Longchuan Li and Cong Yan</i>
08:00-08:15 17:00-17:15	#35		ABOUT THE DISTRIBUTION OF TRACTION EFFORTS BETWEEN THE PROPULSION DEVICES OF WALKING ROBOTS <i>Eugene Briskin, Vitaly Platonov and Liliya Smirnaya</i>
08:15-08:30 17:15-17:30	#37		REGULARITIES OF CONTACT BEHAVIOR OF SMALL SUPPORTING ELEMENTS (FEET) OF WALKING MACHINES AND ROBOTS WITH WEAKLY BEARING AND WATER-SATURATED SOILS <i>Vladimir Arykantsev, Vadim Chernyshev, Yaroslav Kalinin and Nikolay Sharonov</i>
08:30-08:45 17:30-17:45	#46		REALISTIC 3D SIMULATION OF A HYBRID LEGGED-WHEELED ROBOT <i>Inês Soares, Vítor H. Pinto, José Lima and Paulo Costa</i>

**Session – M3: Inspection**  
**Session Chair: Tariq Sattar**

**Time: 09:00 – 09:45 (UTC), 18:00 – 18:45 (JST)**

Time	Paper ID	Proc Page	Presentation
09:00-09:15 18:00-18:15	#31		RESIDUAL WATER REMOVAL MECHANISM FOR OBTAINING CLEAR IMAGES WITH SEWER PIPE INSPECTION ROBOT <i>Kosuke Uchiyama, Hiroto Sato, Fumio Ito, Shunichi Kurumaya and Taro Nakamura</i>
09:15-09:30 18:15-18:30	#33		WIRELESS COMMUNICATION WITH MOBILE INSPECTION ROBOTS OPERATING WHILE SUBMERGED INSIDE OIL STORAGE TANKS <i>N'Zebo Richard Anvo, Aman P Kaur and Tariq P Sattar</i>
09:30-09:45 18:30-18:45	#41		CLIMBING ROBOT TO PERFORM RADIOGRAPHY OF WIND BLADES <i>Tariq Sattar, N'Zebo Anvo, Gabriela Gallegos Garrido, Aman Kaur, Vitor Marques, Peter Routledge and Karen Markham</i>

**Keynote Address – 1**  
**Session Chair: Osman Tokhi**

**Time: 10:00 – 11:00 (UTC), 19:00 – 20:00 (JST)**

Time	Paper ID	Proc Page	Presentation
10:00-11:00 19:00-20:00	PL1		CATEGORIZING EXTREME ENVIRONMENTS AND PREDICTING SUCCESS <i>Robin R. Murphy</i>

**Session – M4: Outdoor and Field Robotics**  
**Session Chair: Taro Nakamura**

**Time: 11:15 – 12:45 (UTC), 20:15 – 21:45 (JST)**

Time	Paper ID	Proc Page	Presentation
11:15-11:30 20:15-20:30	#7		HORIZONTAL DRILLING WITH SEABED ROBOTIC EXPLORER <i>Ryosuke Tokoi, Wataru Toyama, Kazuki Tsumura, Tomoki Watanabe, Manabu Okui, Taro Nakamura and Hiroshi Yoshida</i>
11:30-11:45 20:30-20:45	#22		EXCAVATION EXPERIMENT OF EARTH WORM TYPE SEABED EXPLORATION ROBOT IN ACTUAL SEA AREA <i>Manabu Okui, Ryosuke Tokoi, Wataru Toyama, Kazuki Tsumura, Keita Isaka, Taro Nakamura and Hiroshi Yoshida</i>
11:45-12:00 20:45-21:00	#26		EVALUATION OF OPTIMAL CLEANING TOOLS FOR THE DEVELOPMENT OF A CLEANING ROBOT FOR GREASE FROM VENTILATION DUCTS <i>Yuta Yamanaka, Takehiro Hitomi, Fumio Ito and Taro Nakamura</i>
12:00-12:15 21:00-21:15	#34		WORK PATH PLANNING FOR AUTOMATIC OPERATION CONSIDERING THE MOTION PERFORMANCE OF A PADDY FIELD WEEDING ROBOT <i>Hiroaki Uchida, Seiya Moro, Kenji Nomura and Satoharu Sekine</i>
12:15-12:30 21:15-21:30	#43		DEVELOPMENT OF THE OBJECT TRANSFER ROBOT WITH VARIABLE HEIGHT USING A PANTOGRAPH-TYPE JACK SYSTEM <i>Kazushi Kurasawa, Hyouga Sugiyama, Satoshi Muramatsu, Katuhiko Inagaki, Daisuke Chugo and Hiroshi Hashimoto</i>
12:30-12:45 21:30-21:45	#3		SEMI-AUTONOMOUS MOBILE ROBOT FOR ENVIRONMENTAL SURFACES DISINFECTIONS AGAINST SARS-COV-2 <i>Hector Montes, Humberto Rodriguez, Octavio Echeverria and Victor Perez</i>

## Tuesday 31 August 2021

<b>Time: 05:30 – 06:00 (UTC), 14:30 – 15:00 (JST)</b>	
05:30-06:00 14:30-15:00	Conference Registration

<b>Session – T1: Biped Locomotion</b>			
<b>Session Chair: Karsten Berns</b>			
<b>Time: 06:00 – 07:00 (UTC), 15:00 – 16:00 (JST)</b>			
Time	Paper ID	Proc Page	Presentation
06:00-06:15 15:00-15:15	#10		STUDYING THE TWO-LEGGED WALKING SYSTEM WITH VIDEO CAPTURE METHODS <i>Alexander Pechurin, Sergey Jatsun and Andrey Fedorov</i>
06:15-06:30 15:15-15:30	#14		STACKED MODULATION ARCHITECTURE FOR SIMULTANEOUS EXPLORATION AND NAVIGATION OF A BIPED ROBOT <i>Tomomichi Sugihara and Takanobu Yamamoto</i>
06:30-06:45 15:30-15:45	#21		CONTINUOUS INVERSE KINEMATICS IN SINGULAR POSITION <i>Patrick Vonwirth and Karsten Berns</i>
06:45-07:00 15:45-16:00	#38		ANALYSIS OF BIPED ROBOT ON UNEVEN TERRAIN BASED ON FEED-FORWARD CONTROL <i>Cong Yan, Fumihiko Asano, Yanqiu Zheng and Longchuan Li</i>

<b>Session – T2: Innovative design of CLAWAR</b>			
<b>Session Chair: Dimitris Chrysostomou</b>			
<b>Time: 07:15 – 08:00 (UTC), 16:15 – 17:00 (JST)</b>			
Time	Paper ID	Proc Page	Presentation
07:15-07:30 16:15-16:30	#9		THE FLATWORM-LIKE PEDAL LOCOMOTORY ROBOTWORMESH-II: FUNDAMENTAL PROPERTIES OF PEDALWAVE LOCOMOTION <i>Ganegoda Vidanage Charaka Rasanga, Ryuichi Hodoshima and Shinya Kotosaka</i>



07:30-07:45 16:30-16:45	#13		EXPERIMENTAL INVESTIGATION OF LOCOMOTIVE EFFICIENCY OF A SOFT ROBOTIC EEL WITH A LARGELY PASSIVE BODY <i>Dinh Quang Nguyen and Van Anh Ho</i>
07:45-08:00 16:45-17:00	#24		NON-ASSEMBLY WALKING MECHANISM FOR ROBOTIC IN-PIPE INSPECTION <i>George Jackson-Mills, Basil Shead, James Collett, Masego Mphake, Nicholas Fry, Andrew Barber, Jordan Boyle, Robert Richardson, Andrew Jackson and Shaun Whitehead</i>

**Keynote Address – 2**  
**Session Chair: Daisuke Chugo**

**Time: 08:15 – 09:15 (UTC), 17:15 – 18:15 (JST)**

Time	Paper ID	Proc Page	Presentation
08:15-09:15 17:15-18:15	PL2		SERVICE ROBOT TECHNOLOGY BASED ON HUMAN UNDERSTANDING <i>Hajime Asama</i>

**Session – T3: Legged locomotion**  
**Session Chair: Taro Nakamura**

**Time: 09:30 – 10:45 (UTC), 18:30 – 19:45 (JST)**

Time	Paper ID	Proc Page	Presentation
09:30-09:45 18:30-18:45	#12		SIMULATION-BASED CLIMBING CAPABILITY ANALYSIS FOR QUADRUPEDAL ROBOTS <i>Kentaro Uno, Giorgio Valsecchi, Marco Hutter and Kazuya Yoshida</i>
09:45-10:00 18:45-19:00	#27		IMPROVED ENERGY EFFICIENCY VIA PARALLEL ELASTIC ELEMENTS FOR THE STRAIGHT-LEGGED VERTICALLY-COMPLIANT ROBOT SLIDER <i>Ke Wang, Roni Permana Saputra, James Paul Foster and Petar Kormushev</i>
10:00-10:15 19:00-19:15	#32		SIX-LEGGED ROBOT OVERTURN FROM AN EMERGENCY POSITION ON THE BACK UNDER THE INFLUENCE OF HINDRANCE <i>Yury F. Golubev, Victor V. Koryanov and Elena V. Melkumova</i>
10:15-10:30 19:15-19:30	#39		PASSIVE GRIPPING FOOT FOR A LEGGED ROBOT TO MOVE OVER ROUGH TERRAIN <i>Sho Hakamada and Sadayoshi Mikami</i>

10:30-10:45 19:30-19:45	#40		ENHANCING LEGGED ROBOT NAVIGATION OF ROUGH TERRAIN VIA TAIL TAPPING <i>Daniel Soto, Kelimar Diaz and Daniel Goldman</i>
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## Wednesday 1 September 2021

<b>Time: 05:30 – 06:00 (UTC), 14:30 – 15:00 (JST)</b>	
05:30-06:00 14:30-15:00	Conference Registration

<b>Session – W1: Innovative Actuators and Power Supplies &amp; Human-Machine/ Human-Robot interaction</b>			
<b>Session Chair: Sho Yokota</b>			
<b>Time: 06:00 – 07:00 (UTC), 15:00 – 16:00 (JST)</b>			
Time	Paper ID	Proc Page	Presentation
06:00-06:15 15:00-15:15	#4		A LOW-COST, LIGHTWEIGHT, AND COMPLIANT LEG STRUCTURE FOR TERRESTRIAL AND AQUATIC WALKING ROBOTS <i>Peter Billeschou, Cao Do, Jørgen Larsen and Poramate Manoonpong</i>
06:15-06:30 15:15-15:30	#44		DESIGN AND MODELLING OF A MODULAR ROBOTIC JOINT <i>Marco Rocha, Vítor Pinto, José Lima and Paulo Costa</i>
06:30-06:45 15:30-15:45	#42		THE SPHERICAL PEDAL CONTROL DEVICE FOR OMNI-DIRECTIONAL MOBILE ROBOT OPERATION <i>Thawanrat Siriwattanalerd, Ryosuke Sugimoto, Satoshi Muramatsu and Katsuhiko Inagaki</i>
06:45-07:00 15:45-16:00	#45		MODELLING OF PEDESTRIANS CROSSING A CROSSWALK AND ROBOT NAVIGATION BASED ON ITS CHARACTERISTICS <i>Shunsuke Yamada, Daisuke Chugo, Satoshi Muramatsu, Sho Yokota, Jin-Hua She and Hiroshi Hashimoto</i>

<b>Session – W2: Wearable Devices and Assistive Robotics</b>			
<b>Session Chair: Khaled Goher</b>			
<b>Time: 07:15 – 08:00 (UTC), 16:15 – 17:00 (JST)</b>			
Time	Paper ID	Proc Page	Presentation
07:15-07:30 16:15-16:30	#1		EVALUATION METHOD OF GAIT MOTION OF A PATIENT RECEIVED TOTAL KNEE ARTHROPLASTY USING CORRELATION BETWEEN MEASUREMENT DATA AND EVALUATION SCORE <i>Koji Makino, Masahiro Nakamura, Ryo Hagihara, Hidenori Omori, Yoshinobu Hanagata, Shohei Ueda, Kohei Shirataki and Hidetsugu Terada</i>

07:30-07:45 16:30-16:45	#8		LIGHTWEIGHT LOCOMOTION ASSISTANT FOR PEOPLE WITH MILD DISABILITIES <i>Gonçalo Neves, Joao Sequeira and Cristina Santos</i>
07:45-08:00 16:45-17:00	#23		POSSIBILITY OF GETTING ON/OFF PUBLIC VEHICLE BY MANUAL WHEELCHAIR WITH 4 DEGREES OF FREEDOM CONTACT ARM MECHANISM <i>Fumiaki Takemori and Ryoga Hayashi</i>

**Keynote Address – 3**  
**Session Chair: Manuel Silva**

**Time: 08:15 – 09:15 (UTC), 17:15 – 18:15 (JST)**

Time	Paper ID	Proc Page	Presentation
08:15-09:15 17:15-18:15	PL2		QUADRUPED ROBOTS FOR CHALLENGING TASKS ON UNSTRUCTURED TERRAINS <i>Claudio Semini</i>

**Session – W3: Planning and Control**  
**Session Chair: Eugene Briskin**

**Time: 09:30 – 11:00 (UTC), 18:30 – 20:00 (JST)**

Time	Paper ID	Proc Page	Presentation
09:30-09:45 18:30-18:45	#6		LEARNING AND TRANSFER OF MOVEMENT GAITS USING REINFORCEMENT LEARNING <i>David Waidner and Marcus Strand</i>
09:45-10:00 18:45-19:00	#11		ROLLING RESISTANCE MODEL AND CONTROL OF SPHERICAL ROBOT <i>Alexander Kilin, Yury Karavaev and Tatiana Ivanova</i>
10:00-10:15 19:00-19:15	#19		AUTOMATIC GENERATION OF RANDOM STEP ENVIRONMENT MODELS FOR GAZEBO SIMULATOR <i>Ruslan Gabdrahmanov, Tatyana Tsoy, Mikhail Svinin and Evgeni Magid</i>
10:15-10:30 19:15-19:30	#25		THE MOTION CONTROL RESEARCH OF THE MOBILE ROBOT WITH VIBRATING PROPULSION DEVICE WHICH DISCRETELY INTERACTING WITH THE SUPPORTING SURFACE <i>Denis Bordyugov, Eugene Briskin and Nikolay Sharonov</i>

10:30-10:45 19:30-19:45	#30	EXPERIMENTAL INVESTIGATIONS OF THE CONTROLLED MOTION OF THE ROLLER RACER ROBOT <i>Alexander Kilin, Yuriy Karavaev and Kirill Yefremov</i>
10:45-11:00 19:45-20:00	#36	GENERATION OF THE SELF-MOTION MANIFOLDS OF A FUNCTIONALLY REDUNDANT ROBOT USING MULTI-OBJECTIVE OPTIMIZATION <i>Ilka Banfield and Humberto Rodriguez</i>
11:00-11:15 20:00-20:15	Awards Ceremony	
11:15-11:30 20:15-20:30	Closing Session	