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Robotics for Sustainable Future

CLAWAR 2021

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Forward

Climbing and Walking Robots (CLAWAR) started with a six-month exploratory phase in 1996 by four European organizations, namely University of Portsmouth, Royal Military Academy, FZI and RISO with the view to identify robotic stakeholders across Europe. The outcome was initiation of the CLAWAR thematic network of excellence supported by the European Commission over two phases, namely CLAWAR1 under the EC Brite Euram programme during 1998–2002 and CLAWAR2 under the EC GROWTH programme during 2002–2005.

CLAWAR Association was established by end of 2005 to continue the activities of the CLAWAR Network globally, with the mission to advance robotics for the public benefit. The association was registered in March 2006 with the Companies House in the UK as a non-profit-making limited company by guarantee and in 2012 with the Charities Commission in the UK as a charitable organization.

The CLAWAR annual conference series is one of the main activities of CLAWAR Association. The first nine issues of the conference starting from 1998 were held in locations across Europe and further issues in various countries worldwide. The COVID-19 pandemic has had an impact on mode of participation in the conference, and while issues to 22 (2019) were held in physical participation mode, virtual participation mode has been exercised for issues 23 (2020, Russian Federation) and issue 24 (2021, Japan). The CLAWAR conference series has established itself as a popular and high-profile platform for networking and dissemination of research and development findings in the area of mobile robotics and associated technologies.

Preface

CLAWAR 2021 is the twenty-fourth edition of International Conference Series on Climbing and Walking Robots and the Support Technologies for Mobile Machines. The conference is organized by CLAWAR Association in collaboration with Kwansei Gakuin University on a virtual platform in Takarazuka, Japan, during 30 August – 01 September 2021.

CLAWAR 2021 brings new developments and new research findings in robotics technologies within the framework of “robotics for sustainable future”. The topics covered include wearable devices assistive robotics from augmentation to full support for those with mobility disorders, innovative designs of components and full systems and application-specific robotic solutions.

The CLAWAR 2021 conference includes a total of 42 regular submission articles from research institutions worldwide. This number has been arrived at through rigorous review of initial submissions, where each paper initially submitted has received at least three reviews. The conference further features three plenary presentations;

Categorizing extreme environments and predicting success

Robin R. Murphy, Texas A&M University, USA

Quadruped robots for challenging tasks on unstructured terrains

Claudio Semini, Istituto Italiano di Tecnologia, Italy

Service robotics for system integration

Hajime Asama, University of Tokyo, Japan

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.

August 2021

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List of Abbreviations

Abd	Abduction
ABS	Acrylonitrile butadiene styrene
AC	Alternating current
ADC	Analog-to-digital converter
Add	Adduction
AI	Artificial intelligence
API	American Petroleum Institute
ATEX	Atmospheres explosives
BL	Body length
BLDC	Brushless direct current
CAD	Computer aided design
CAN	Controlled area network
CANOpen	Controlled area network open protocol
CBT	Canonical biped track
CCDF	Complementary cumulative distribution function
CCW	Counter clock-wise
CNC	Computer numerical control
COM	Centre of mass
COT	Cost of transport
CPU	Central processing unit
CW	Clock-wise
DC	Direct current
DLS	Damped least square
DoF	Degrees of freedom
DZC	Dead zone compensation
ECHA	European Chemical Agency
EMW	Electro-magnetic wave
ENG	Elevation-and-normal grid
EoM	Equation of motion
EPA	Environmental Protection Agency

EVA	Ethylene-vinyl acetate
EWEA	European Wind Energy Association
FABRIK	Forward and backward reaching inverse kinematics
FF	Feed forward
FK	Forward kinematics
FPS	Floating processing unit
GIA	Gravito-inertial acceleration
GNSS	Global navigation satellite system
GP	Gaussian process
GPS	Global positioning system
GPU	Graphical processing unit
GUI	Graphical user interface
HMS	Human machine system
I	Integral
IBR	Inchworm boring robot
ID	Identifier
IEC	International Electro-technical Commission
IK	Inverse kinematics
IMC	Internal model control
IMU	Inertial measurement unit
IP	Ingress protection
I2C	Inter integrated circuit
LED	Light emitting diode
LIDAR	Light detection and ranging
LiPo	Lithium polymer
LIRS	Laboratory of Intelligent Robotic Systems
MCU	Microprocessor control unit
MDBF	Mean displacement before failure
MDP	Markov decision process
ML	Machine learning
MOEA	Multi objective evolutionary algorithm
MOGA	Multi-objective genetic algorithms
MSS	Musculoskeletal system
NDT	Non-destructive testing
NMT	Network management
NSGA	Non-sorting genetic algorithm
ODE	Open dynamics engine
OpenGL	Open graphics library
PC	Personal computer
PCB	Printed circuit board
PD	Proportional derivative
PI	Proportional integral
PID	Proportional-integral-derivative
PIG	Pipeline inspection gauge
PLA	Poly-lactic acid

PPM	Profile position mode
PPO	Proximal policy optimization
PVA	Poly vinyl alcohol
PVC	Poly-vinyl chloride
PWM	Pulse width modulation
RC	Radio controlled
RF	Radio frequency
RHex	Robotic hexapod
RMS	Root mean square
ROS	Robot operating system
RS	Recommended standard
RSE	Random step environment
RTF	Real time factor
RTK	Real time kinematic
RW	Rimless wheel
SAC	Soft-actor critic
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SC	Smart cane
SDLS	Selectively damped least square
SE	Squared exponential
SEAN	Simultaneous exploration and navigation
SLS	Selective laser sintering
SSE	Screw subsurface explorer
SSH	Secure shell
STL	Stereolithography
SURF	Speeded up robust features
SW	Smart walkers
SLAM	Simultaneous localisation and mapping
THA	Total hip arthroplasty
TSM	Tumble stability margin
UART	Universal asynchronous receiver transmitter
UCB	Upper confidence bound
UGV	Unmanned ground vehicle
ULV	Ultra low volume
USAR	Urban search and rescue
USB	Universal serial bus
UT	Underwater technology
UTP	Technological University of Panama
UVC	Ultra violet C
WHO	World Health Organization
WT	Wind turbine
WTB	Wind turbine blade
WTT	Wind turbine tower
ZMP	Zero-moment point