INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS

HIGHLIGHTS 2015

IJARS ACTIVITIES HIGHLIGHTS
VIDEO SERIES
WOMEN IN ROBOTICS

ROBOTS IN INDUSTRY
INTERVIEWS
OVERVIEWS

FROM THE MANAGING EDITOR

Dear readers,

12 is a number that bears symbolism and significance across many cultures. For the International Journal of Advanced Robotic Systems this is no exception. The end of celebratory activities that marked the journal's 10th anniversary have ended with the start of IJARS's current 12th volume. Many of these activities have enriched the journal's portfolio and strengthened its connection with the robotics community.

This year's Highlights present you with these activities and the ones that are to follow. This promotional feature also introduces a special section dedicated to a theme that has been a center of feverish debates and discussions for the last couple of years – the use of robots in industry and the connection between the research conducted in industry and academia.

The 12th volume has also seen a change in the IJARS's management – I have succeeded Ms. Natalia Reinic on a position of the Managing Editor. For all the dedication to this journal, uncountable hours of hard work, her guidance and good counsel I thank her.

I hope you will enjoy reading the feature we have prepared for you. Although it is no longer a celebratory, every year of working with our collaborators is a celebration of scientific achievements. Thank you all for being part of the journal, for supporting the free dissemination of knowledge, and for assisting us to grow in quality and consistency.

Viktorija Zgela

Highlights 2015 is a promotional supplement to the International Journal of Advanced Robotic Systems, an Open Access scientific journal at the forefront of publishing research in the field of robotics for 11 years, following the mission to give authors global recognition and to actively ease the fundamental problem of limited accessibility to knowledge offering scientific and education resources at no cost.

It targets a wide, international robotics community and addresses both practicing professionals and researchers in the field and its specialty areas.

INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS (IJARS)

- OPEN ACCESS, ALL PUBLISHED CONTENT DISTRIBUTED ONLINE FOR FREE
- FIRST OPEN ACCESS ROBOTICS JOURNAL PUBLISHED IN THE STM FIELD AND INDEXED IN ISI THOMSON REUTERS
- STRICT DOUBLE BLIND PEER-REVIEW
- INTERNATIONAL AUTHORSHIP AND READERSHIP
- VIDEO CHANNEL

OPEN ACCESS

TITLE	International Journal of Advanced Robotic Systems (IJARS)
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CURRENT VOLUME	12
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SCIENTIFIC PAPERS PUBLISHED	1283
PUBLISHED AUTHORS	3671

CONTENTS

2014 has been a remarkable year for the International Journal of Advanced Robotic Systems in many aspects. We have marked our 10th anniversary with numerous celebratory activities, implemented new features and started new projects that have enabled our collaborators to choose among several ways of cooperating with the journal. With the innovative new projects we continue to support the openness of science and unrestricted access to the world knowledge presented in the published papers. Only when the knowledge is freely accessible and widely disseminated can we expect to see the growth in innovations and discoveries that will bring the prosperity and improve daily lives across the globe. The Open Access model under which all IJARS papers are published allows the journal to follow this vision.

IJARS's unique structure of 13 topics that promote different research foci in robotics remain the backbone of the journal. This diversity of subjects allows the journal to pay attention to the emerging topics in robotics and include them in its scope. The two-level decision making system (Topic Editors-in-Chief and Associate Editors) ensure that the review is both rigorous and fair, and that all submitting authors receive the same treatment. The reviewers who conduct the evaluation of the articles contribute to the steady growth in quality of the papers. For their laborious and diligent work on reviewing the submissions we are very grateful and indebted.

With this new issue of Highlights we would like to introduce all our readers to the achievements accomplished in 2014/ at the beginning of 2015, and our plans for the future. Being a part of the scientific community it is one's imperative to keep an eye on the current developments and discussions that preoccupy the members of the very same community. This is why we have included a section tackling current hot topic in robotics – the use of robots in industry. The prevailing public attitude is that the robots are stealing people's jobs and that we should fear them. The Internatioal Journal of Advanced Robotic Systems, on the contrary, wants to shed a positive light on robots: robots that are employed not only in production facilities, robots that are used for medical/nursing purposes, robots that are at the center of the entertainment industry, robots that help people in their daily routines, those that save lives... And roboticists that are behind the scenes of all these advancements – either conducting the research in academia or industry to make the integration and inclusion of robots in our lives possible - have, with their participation in this supplementary issue, contributed to this goal.

IJARS ACTIVITIES HIGHLIGHTS

BOOK OF ABSTRACTS

The International Journal of Advanced Robotic Systems has published 194 papers in Volume 11, 2014. With the aim to comprehensively present all these papers in just one place and to ease the selection of the most interesting findings, we have introduced the Book of Abstracts. This feature contains the titles, authors, abstracts, keywords and links to full papers of all published articles. The Book of Abstracts can be found under Articles tab on our web page, from where you can freely access and download it.

INVITED PAPERS

OPEN ACCESS

In order to facilitate the community's demand for high-quality papers that follow the latest research trends and provide a comprehensive analysis of the latter, the IJARS team has introduced a series of invited articles. With the aim to ceaselessly work on increasing the quality of the journal itself, we continue with this initiative throughout 2015.
Take a look at the list of already published articles available for a free download on our web page and make sure to regularly check our homepage for updates.

VOLUME 12, 2015

IDENTIFYING GROUND-ROBOT IMPEDANCE TO IMPROVE TERRAIN ADAPTABILITY IN RUNNING ROBOTS
Juan C. Arevalo, Daniel Sanz-Merodio, Manuel Cestari and Elena Garcia

DEVELOPMENT OF A COGNITIVE ROBOTIC SYSTEM FOR SIMPLE SURGICAL TASKS
Riccardo Muradore, Paolo Fiorini, Gokhan Akgun, Duygun Erol Barkana, Marcello Bonfe, Fabrizio Boriero, Andrea Caprara, Giacomo De Rossi, Riccardo Dodi, Ole Jakob Elle, Federica Ferraguti, Lorenza Gasperotti, Roger Gassert, Kim Mathiassen, Dilla Handini, Olivier Lambercy, Lin Li, Maarja Kruusmaa, Auralius Oberman Manurung, Giovanni Meruzzi, Ho Quoc Phuong Nguyen, Nicola Preda, Gianluca Riolfo, Asko Ristolainen, Alberto Sanna, Cristian Secchi, Marco Torsello and Asım Evren Yantac

CURRENT CAPABILITIES AND DEVELOPMENT POTENTIAL IN SURGICAL ROBOTICS
Mathias Hoeckelmann, Imre J. Rudas, Paolo Fiorini, Frank Kirchner and Tamas Haidegger

ROBOTIC SURGERY – A PERSONAL VIEW OF THE PAST, PRESENT AND FUTURE
Brian Davies

TP-SPACE RRT: KINEMATIC PATH PLANNING OF NON-HOLONOMIC ANY-SHAPE VEHICLES
Mauro Bellone, José-Luis Blanco-Claraco and Antonio Giménez-Fernández

VOLUME 11, 2014

LEGO-BASED ROBOTICS IN HIGHER EDUCATION: 15 YEARS OF STUDENT CREATIVITY
Ethan Danahy, Eric Wang, Jay Brockman, Adam Carberry, Ben Shapiro and Chris B. Rogers

AN OVERVIEW ON GRIPPING FORCE MEASUREMENT AT THE MICRO AND NANO-SCALES USING TWO-FINGERED MICROROBOTIC SYSTEMS
Mokrane Boudaoud and Stephane Regnier

STRIDE II: A WATER STRIDER-INSPIRED MINIATURE ROBOT WITH CIRCULAR FOOTPADS
Onur Ozcan, Han Wang, Jonathan D. Taylor and Metin Sitti

A TAXONOMY OF VISION SYSTEMS FOR GROUND MOBILE ROBOTS
Jesus Martínez-Gómez, Antonio Fernández-Caballero, Ismael García-Varea, Luis Rodríguez and Cristina Romero-González

ZEPPELIN: DISTRIBUTED PATH PLANNING USING AN OVERHEAD CAMERA NETWORK
Andreagiovanni Reina, Luca Maria Gambardella, Marco Dorigo and Gianni A. Di Caro

ADAPTIVE MULTI-SENSOR PERCEPTION FOR DRIVING AUTOMATION IN OUTDOOR CONTEXTS
Annalisa Milella and Giulio Reina

BIOLOGICALLY-INSPIRED CONTROL ARCHITECTURE FOR MUSICAL PERFORMANCE ROBOTS
Jorge Solis, Kenichiro Ozawa, Maasaki Takeuchi, Takafumi Kusano, Shimpei Ishikawa, Klaus Petersen and Atsuo Takanishi

SMAC — A MODULAR OPEN SOURCE ARCHITECTURE FOR MEDICAL CAPSULE ROBOTS
Marco Beccani, Ekawahyu Susilo, Christian Di Natali and Pietro Valdastri

FORTHCOMING ARTICLES

A NEW MODULAR, AUTONOMOUSLY RECONFIGURABLE MANIPULATOR PLATFORM
M. Reza Emami and Jason A. Kereluk

PERFORMANCE COMPARISON BETWEEN FEDERICA HAND AND LARM HAND
Giuseppe Carbone, Cesare Rossi and Sergio Savino

THE THEORY OF NEURAL COGNITION APPLIED TO ROBOTICS
Claude Touzet

OVERCOMING BARRIERS AND INCREASING INDEPENDENCE: SERVICE ROBOTS FOR ELDERLY AND DISABLED PEOPLE
Marion Hersh

TEN YEARS OF COOPERATION BETWEEN MOBILE ROBOTS AND SENSOR NETWORKS
Jesus Capitán Fernández, Jose Ramiro Martinez-de-Dios, Ivan Maza, Felipe Ramon Fabresse and Anibal Ollero

EDITOR’S CHOICE

The Topic Editors-in-Chief have selected a number of papers that stand out in terms of novelty and the quality of presented reseach. This list will be updated twice a year, as new and interesting content is pubished regularly in our journal. You can find the list of selected papers under Editor’s Choice tab on our homepage.

HUMAN HAND MOTION ANALYSIS AND SYNTHESIS OF OPTIMAL POWER GRASPS FOR A ROBOTIC HAND
Francesca Cordella, Loredana Zollo, Antonino Salerno, Dino Accoto, Eugenio Guglielmelli and Bruno Siciliano

AN UNDERACTUATED MULTI-FINGER GRASPING DEVICE
Cesare Rossi and Sergio Savino

HOVERING BY GAZING: A NOVEL STRATEGY FOR IMPLEMENTING SACCADIC FLIGHT-BASED NAVIGATION IN GPS-DENIED ENVIRONMENTS
Augustin Manecy, Nicolas Marchand and Stéphane Viollet

DISTRIBUTED COMPUTATION IN A QUADRUPEDAL ROBOTIC SYSTEM
Daniel Kuehn, Felix Bernhard, Armin Burchardt, Moritz Schilling, Tobias Stark, Martin Zenzes and Frank Kirchner

TOWARDS MOBILE MICROROBOT SWARMS FOR ADDITIVE MICROMANUFACTURING
David Cappelleri, Dimitrios Efthymiou, Ashesh Goswami, Nikolaos Vitoroulis and Michael Zavlanos

A FLYING ROBOT LOCALIZATION METHOD BASED ON MULTI-SENSOR FUSION
Changan Liu, Sheng Zhang, Hua Wu and Ruifang Don

EXTERNAL JOINT TORQUE-BASED ESTIMATION OF CONTACT INFORMATION
Nejc Likar and Leon Žlajpah

EVALUATING THE FIN-RAY TRAJECTORY TRACKING OF BIO-INSPIRED ROBOTIC UNDULATING FINS VIA AN EXPERIMENTAL-NUMERICAL APPROACH
Xiaojia Xiang, Tianjiang Hu, Han Zhou and Zhaowei Ma

DESIGN AND ROLLING ANALYSIS OF A NOVEL DEFORMABLE MOBILE POLYHEDRON ROBOT
Yaobin Tian, Xiangzhi Wei, Ajay Joneja and Yan-An Yao

ACTIVE ELBOW ORTHOSIS
Tomas Ripel, Jiri Krejsa, Jan Hrbacek and Igor Cizmar

RAIL-GUIDED MULTI-ROBOT SYSTEM FOR 3D CELLULAR HYDROGEL ASSEMBLY WITH COORDINATED NANOMANIPULATION
Huaping Wang, Qing Shi, Masahiro Nakajima, Masaru Takeuchi, Tao Chen, Pei Di, Qiang Huang and Toshio Fukuda

A HIERARCHICAL FUZZY CONTROL DESIGN FOR INDOOR MOBILE ROBOT
Foudil Abdessemed, Mohammed Faisal, Muhammed Emmadeddine, Ramdane Hedjar, Khalid Al-Mutib, Mansour Alsulaiman and Hassan Mathkour

A NOVEL QUAD HARMONY SEARCH ALGORITHM FOR GRID-BASED PATH FINDING
Saso Koceski, Stojanche Panov, Natasa Koceska, Pierluigi Beomonte Zobel and Francesco Durante

A GLOBAL OBSTACLE-AVOIDANCE MAP FOR ANTHROPOMORPHIC ARMS
Cheng Fang and Xilun Ding

AN ADVANCED APPROACH TO EXTRACTION OF COLOUR TEXTURE FEATURES BASED ON GLCM
Miroslav Benco, Robert Hudec, Patrik Kamencay, Martina Zachariasova and Slavomir Matuska

PARTICLE-FILTER-BASED POSE ESTIMATION FROM CONTROLLED MOTION WITH APPLICATION TO VISUAL SERVOING
Abdul Hafez Abdul Hafez and Enric Cervera

A CROSS-DOMAIN SURVEY OF METRICS FOR MODELLING AND EVALUATING COLLISIONS
Jeremy A. Marvel and Roger Bostelman

RESEARCH ON ONE BIO-INSPIRED JUMPING LOCOMOTION ROBOT FOR SEARCH AND RESCUE
Dunwen Wei and Wenjie Ge

OPEN ACCESS

SPECIAL ISSUES

Although the journal's scope covers all robotic fields and subfields, there is always a need to highlight topics that are of a particular interest or that comprehensively summarise the end of a certain project/conference in a form of a Special Issue.

This is the list of Special Issues IJARS has published in Volume 11 (2014) and Volume 12 (2015):

TELEROBOTICS AND SYSTEMS ENGINEERING FOR SCIENTIFIC FACILITIES

This special issue is focused on promoting telerobotic remote handling technologies integrated with system engineering. The main objective is to show the current state of the art of telerobotics and discuss the main challenges in the application of telerobotics in scientific facilities, where methods of system engineering become the most suitable way in integrating robotics in order to manage these facilities properly. The papers were produced by researchers participating to the PURESAFE conference, funded by Marie Curie Actions, specifically the Seventh Framework Programme led by Finland's Tampere University of Technology (TUT), in partnership with Universidad Politécnica de Madrid (UPM) in Spain, Karlsruhe Institute of Technology (KIT) in Germany, European Organization for Nuclear Research (CERN) in Switzerland, Helmholtz Centre for Heavy Ion Research/Facility for Ion and Antiproton Research (GSI) in Germany, Oxford Technologies Ltd (OTL) in the UK and SenseTrix Ltd and bgator Ltd Finland.

GUEST EDITORS

Prof. Manuel Ferre, Centre for Automation and Robotics (CAR UPM-CSIC), Spain
Prof. Jouni Mattila, Tampere University of Technology (TUT), Finland
Prof. Bruno Siciliano, University of Napoli, Italy
Prof. Pierre Bonnal, CERN, Switzerland

DESIGN, FABRICATION, CONTROL, AND PLANNING OF MULTIPLE MOBILE MICROROBOTS

"Design, Fabrication, Control, and Planning of Multiple Mobile Microrobots" Special Issue (SI) focuses on new approaches and future directions on developing microrobotic systems where multiple mobile robots operate in parallel to perform complex manipulations. Such manipulations are increasingly playing a major role in biology and medicine as for example by realizing targeted drug therapy. They are also bringing about a new paradigm in the manufacturing of miniature devices by enabling microassembly of heterogeneous components in three dimensions.
The microrobots can be actuated in a variety of ways ranging from electrical and magnetic to mechanical, optical, and even acoustic or chemical. Design and fabrication of the robots depends a lot on the actuation technique, and becomes quite challenging for autonomous operations within constrained workspaces across large distances and for significant time durations. Furthermore, controlling and planning their motions provide additional challenges, particularly to generate collision-free trajectories independently for each robot with the aim of achieving coordinated behaviors to maximize the overall operation efficiency and reliability. While significant progress has been achieved over the past few years, we are still quite far off from deploying such autonomous microrobot groups in clinical laboratories or industrial manufacturing facilities.

GUEST EDITORS

Dr. Ashis Banerjee, GE Global Resarch, USA
Dr. David Folio, PRISME, Ensi de Bourges, France
Dr. Sarthak Misra, University of Twente, The Netherlands
Dr. Quan Zhou, Aalto University, Finland

MICRO/NANO MECHATRONICS AND AUTOMATION

Micro/Nano technologies have immense application potential in many domains. Mechatronics fuses the areas of technology involving drive and actuation systems, sensors and measurement systems, and microprocessor systems with the analysis and evaluation of the systems' behavior and control systems. As a combination of micro-/nanotechnologies with the mechatronics and automation techniques, micro/nano mechatronics and automation play an important role in such fields as ultrahigh-precision manufacturing technology, biomedical technology, environmental/energy technology, etc. At the same time, the scaling effect in the micro/nano world and performance requirements of micro/nano mechatronic systems pose a great number of challenges to the component design and system integration. As an advancement in micro/nano technology, the development in micro/nano mechatronics and automation systems attracts more and more attention from researchers in the field. This special issue presents and summarizes the most recent developments and ideas in mechatronics and automation at micro/nano scales.

GUEST EDITORS
Dr. Qingsong Xu, University of Macau, China
Dr. Chi Man Vong, University of Macau, China
Dr. Xinyu Liu, McGill University, Canada
Dr. Zuobin Wang, Changchun University of Science and Technology, China
Dr. Li Zhang, Chinese University of Hong Kong, China
Dr. Guo-Ying Gu, Shanghai Jiao Tong University, China

ROBOTICS IN BUILDING AND INFRASTRUCTURE

Robotics applications are an opportunity to advance the industry, including the construction of buildings and infrastructure. They have been rapidly developed in the past few decades. Major improvements can be found in control, sensing, vision, localization, mapping, and planning modules due to the fast development of computer hardware and software. Many researchers and practitioners have started implementing robotics technologies in construction processes. This special issue specifically focuses on research and case studies that demonstrate how robotics technologies and tools can be applied in the construction of buildings and infrastructure.

GUEST EDITORS
Dr. Shih-Chung Kang, National Taiwan University, Taiwan
Dr. Lieyun Ding, Northeastern University, China
Dr. Xiangyu Wang, Australasian Joint Research Centre for BIM, Curtin University, Australia

GESTURE RECOGNITION FOR HUMAN ROBOT INTERACTION

Gesture recognition is a very attractive research topic for its large application in robotics, human computer interaction, domotics, smart factory and so on. By using defined gestures it will be possible to allow quick triggering for man-machine interaction and to lead to more open interoperability especially in hazardous situations or assisted living environments for elder/impaired people. This special issue contains papers that inspect scientific, technological and application challenges on gesture recognition systems with special attention to the practical issues of designing real-world human-robot and human-computer interaction systems and with a focus on real-time vision aspects pertinent to the development of new generation natural user interfaces.

GUEST EDITORS
Dr. Grazia Cicirelli, Institute of Intelligent Systems for Automation, Italy
Dr. Tiziana D'Orazio, Institute of Intelligent Systems for Automation, Italy

SOON TO BE PUBLISHED

DESIGNING BIOINSPIRED ROBOTS

This special issue is dedicated to a new international conference series, which has been promoted by ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) and IARP (International Advanced Robotics Programme). The first conference entitled "Bio-Inspired Robotics" was held on 14-15th May 2014 at the ENEA's Frascati Research Centre. This event was dedicated to young researchers and scholars with promising ideas, methods and products for innovation and technology transfer in the fields of service robots with bio-inspired design and operation.
The conference, which aimed to start a thematic series, was first in a series of events that will be centered on robotics research. It was inspired by the imitation of solutions and functionalities in biological systems with their adaptation to external environments. The "Designing Bioinspired Robots" presents the selection of best papers presented at this conference.

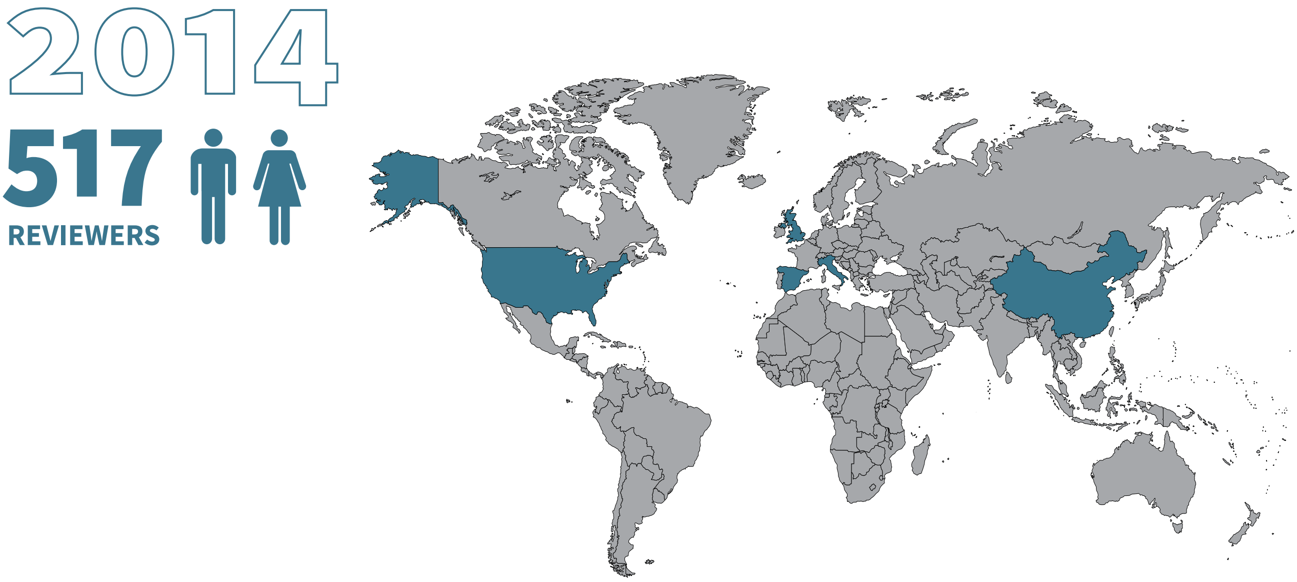
GUEST EDITORS
Dr. Claudio Moriconi, ENEA, Italy
Prof. Marco Ceccarelli, University of Cassino, Italy

You can browse through, read and download all articles published in these Special Issues online.

IJARS TEAM WELCOMES ANY SUGGESTIONS FOR THE START OF SPECIAL ISSUES SO WE INVITE YOU TO CONTACT US AT **ijars@intechopen.com** WITH YOUR IDEAS.

REVIEWERS AWARDS

It is a well-known fact that the reviewers are at the very core of journal publishing. They carefully examine the research, evaluate it, and ensure that only the best and most valuable ones reach the readership and the scientific community. The International Journal of Advanced Robotic Systems recognises and acknowledges the effort and time invested in reviewing the submitted manuscripts and has, thus, decided to award its most dedicated reviewers. To qualify for this award, the reviewer will have to submit a thorough review within the proposed deadline until November 2015. The winners will be selected by Topic Editors-in-Chief and announced in December 2015. Each of the selected reviewers will be awarded with a Certificate of Merit and an opportunity to publish their work in our journal free of APC.



REVIEWERS BY COUNTRY - TOP FIVE

1) UNITED STATES OF AMERICA
2) ITALY
3) PEOPLE'S REPUBLIC OF CHINA
4) SPAIN
5) UNITED KINGDOM

FROM THE PUBLISHING PROCESS MANAGER

The position of Publishing Process Manager for the International Journal of Advanced Robotic Systems gives me a great pleasure to interact with all of you who are in any way involved in creating the journal. First of all, most of my communication goes towards you, dear authors. Day by day, I answer your questions and address your concerns and I try to do that in a timely manner. The whole team is aware of the importance of your work and does its best to provide the support you deserve and we hope we are up to the task most of the time.

Coming to you, dear reviewers, your experience of being in the author's shoes gives you a unique perspective of knowing how it feels to occupy both roles. Having a strict deadline can be very exhausting and sometimes preparing a good review means that you need to put aside some other things. For this reason the entire team behind the journal would like to thank you for your efforts and time spent on review performance. Thank you for being considerate towards the authors, for carefully choosing your words, for your guidance and instructions. We sincerely appreciate everything you do and are grateful to you for keeping the circle closed.

To all who have helped IJARS celebrate its 10th birthday, especially the Editors whose commitment has brought us to where we are today, to all of you who have communicated with the team or myself throughout the years, thank you so much for your cooperation. We are happy to have had the chance to work with you and we are looking forward to continuing down the same path. Your input is always important to us so please do continue sending us your feedback so we could improve our service and focus better on meeting your needs.

Anja Filipovic

EDITORIAL BOARD UPDATE

Owing to the initiative of our Topic Editors, the IJARS Editorial Board structure has been modified over the last year. The new names that have joined the journal, either as Associate Editors or as Editorial Board members, are an invaluable addition and guarantee the maintenance of journal's standards in terms of timely publication timeframe, editorial consistency, international reach, and the quality of papers. The IJARS team welcomes them and looks forward to our fruitful collaboration.

THE EXPERTS THAT HAVE JOINED THE JOURNAL AS NEW ASSOCIATE EDITORS ARE:

SERVICE ROBOTICS

Yukio Takeda, Tokyo Institute of Technology, Japan
Said Zeghloul, University of Poitiers, France
Tian Huang, Tianjin University, China
Erwin-Christian Lovasz, Politehnica University of Timisoara, Romania

MICRO/NANO ROBOTICS

Qingsong Xu, University of Macau, China

HUMAN ROBOT/MACHINE INTERACTION AND AI IN ROBOTICS:

Minoru Asada, Osaka University, Japan
Verena V. Hafner, Humboldt University in Berlin, Germany

MOBILE ROBOTS AND MULTI-ROBOT SYSTEMS

Lorenzo Sabattini, University of Modena and Reggio Emilia, Italy

NEW EDITORIAL BOARD MEMBERS

Sergej Fatikow, University of Oldenburg, Germany
Antoine Ferreira, INSA Centre Val de Loire, Laboratoire PRISME, France
Michaël Gauthier, FEMTO-ST Institute, France
Pasi Kallio, Tampere University of Technology, Finland
Philippe Lutz, FEMTO-ST Institute, France
Sylvain Martel, Polytechnique Montréal, Canada
Bradley Nelson, ETH Zürich, Switzerland
Stéphane Régnier, University Pierre and Marie Curie, France
Metin Sitti, Max Planck Institute for Intelligent Systems, Germany
Andrej Gams, Jozef Stefan Institute, Slovenia
Tadej Petric, Jozef Stefan Institute, Slovenia
Armando Carlos de Pina Filho, Federal University of Rio de Janeiro - UFRJ, Brazil

IJARS HAS 13 TOPICS LEAD BY TOPIC EDITORS-IN-CHIEF AND ASSOCIATE EDITORS THAT ARE OPEN FOR SUBMISSIONS ON AN ONGOING BASIS

ALL ARTICLES ARE PUBLISHED CONTINUOUSLY AND CAN BE FREELY ACCESSED, READ AND DOWNLOADED ONLINE ON IJARS'S OFFICIAL HOMEPAGE.

OPEN ACCESS

ROBOT MANIPULATION AND CONTROL

Topic Editor-in-Chief:
Andrey V. Savkin
University of New South Wales, Australia

Associate Editors I work with:
M. Reza Emami, University of Toronto, Canada
Michael Hoy, The University of New South Wales, Australia
Jayantha Katupitiya, The University of New South Wales, Australia
Pubudu N. Pathirana, Deakin University, Australia
Alexander Pogromsky, Eindhoven University of Technology, Netherlands
Gerasimos Rigatos, Industrial Systems Institute, Greece
Oleg Yakimenko, Naval Postgraduate School, USA

SCOPE AND TOPICS:
Robust, adaptive and optimal control
Autonomous control
Control in telerobotics
Collision avoidance and multi-vehicle systems
Haptics, robot arms and manipulators

FIELD ROBOTICS

Topic Editor-in-Chief:
Yangquan Chen
University of California, Merced, USA

Associate Editors I work with:
Hyo-Sung Ahn, Gwangju Institute of Science and Technology (GIST), Korea
Angelos Amanatiadis, Democritus University of Thrace, Greece
Ke-Cai Cao, Nanjing University of Posts and Telecommunications, China
Nariman Sepehri, University of Manitoba, Canada
Yan Li, Shandong University, China
Holger Voos, University of Luxembourg, Luxembourg

SCOPE AND TOPICS:
Underwater Vehicles
Space Robotics
Ground Vehicles
Autonomous Vehicles
Aerial Vehicles
Agricultural Robotics
Exploration Robotics
Subterranean Robotics
Mining Robotics
Ambient Intelligence
Construction Robots
Environmental Monitoring Robots
Military Robots

MEDICAL ROBOTICS

Topic Editor-in-Chief:
Arianna Menciassi
Sant'Anna School of Advanced Studies, Italy

I am coordinating the topic without the help of Associate Editors, but I heavily rely on the assistance of the Medical Robotics' Editorial Board members.

Currently, my biggest challenge is... merging therapy robotics and bioengineering from macro- to micro-scale. This means exploring novel routes for delivering therapeutic actions where needed with robotic accuracy. This also means merging robotic technologies with knowledge on tissue properties and interaction phenomena between cells and energy/therapy beams. I would like to contribute to nurturing a new generation of researchers and experts without any barriers between robotics and bioengineering. And I would like to invite in the Editorial Board the people who also share this vision with me.

SCOPE AND TOPICS:
Rehabilitation Robotics
Assistive Robotics
Computer Assisted Surgery
Interventional Robotics

VISION SYSTEMS

Topic Editor-in-Chief:
Antonio Fernández-Caballero
University of Castilla-La Mancha, Spain

Associate Editors I work with:
Shengyong Chen, Zhejiang University of Technology, China, University of Cambridge, UK
Grazia Cicirelli, Institute of Intelligent Systems for Automation, Italy
Ismael Garcia-Varea, The University of Castile–La Mancha, Spain
Antonios Gasteratos, Democritus University of Thrace, Greece
D. J. Lee, Brigham Young University, USA
Mohan Sridharan, Texas Tech University, USA

Currently, my biggest challenge is... the combined use of multiple sensor technologies (including body sensors, vision sensors, and brain-computer devices) and affective robots for emotion detection and regulation in virtual and/or real ambiences.

SCOPE AND TOPICS
Camera Networks
Computer Vision
Early and Biological Vision
Face and Gesture Recognition
Hardware Architectures and Software Tools
Human Activity Recognition
Machine Vision
Multicamera Fusion
Motion and Tracking
Novel Vision Sensors
Object Recognition and Classification
Performance Evaluation of Vision Systems
Scene Analysis and Understanding
Segmentation and Grouping
Stereovision and Structure from Motion
Vision-based Navigation and SLAM
3D Reconstruction and Modeling

SERVICE ROBOTICS

Topic Editor-in-Chief:
Marco Ceccarelli
University of Cassino, Italy

Associate Editors I work with:
Gunnar Bolmsjö, University West, Sweden
Giuseppe Carbone, University of Cassino, Italy
M. Reza Emami, University of Toronto, Canada
Marion Hersh, University of Glasgow, UK
Jorge Solis, Karlstad University, Sweden
Houxiang Zhang, Aalesund University College, Norway
Cezary Zieliński, Warsaw University of Technology, Poland
Yukio Takeda, Tokyo Institute of Technology, Japan
Said Zeghloul, University of Poitiers, France
Tian Huang, Tianjin University, China
Erwin-Christian Lovasz, Politehnica University of Timisoara, Romania

Currently, my biggest challenge is... related to ongoing developments at LARM in Cassino - a new humanoid design based on PKM mechanisms, an under-actuated solution of finger mechanisms for improving LARM hand, a new design of service robotic systems for operation in cultural heritage frames and in rehabilitation/training of human limbs, as well as studies of past machine designs. In addition to this, I am involved in activities for preparing project proposals on service robots and organization of IFToMM sponsored conferences (mainly MEDER 2015, HMM2016, MUSME 2017) and the fore-coming 2015 IFToMM World Congress in Taipei which will be held in October.

SCOPE AND TOPICS:
Cleaning and housekeeping
Edutainment
Medical assistance: Surgery assistance, physiotherapy devices
Support to disabled people
Survey and restoration of Cultural Heritage
Assistance to research activities in Pharmacology, Botanics , etc.
Outdoor help (e.g., agricultural help, lawn mowing etc.)
Office help (e.g., guides, receptionist etc.)
Construction
Search and rescue; firefighting
Manufacturing and other industrial help (e.g., food industry)
Humanitarian applications (e.g., demining)
Behavioral intervention; companionship
Caring/nurturing robots

Technologies: papers focusing on specific technologies that are/will be useful for service robotics applications are also welcome. Such technologies include, but are not limited to:

Sensing and Controlled Actuation
Mobility and Motion Planning
Manipulation and Structure Design
Communication
Human-Robot Interaction
Robot Learning

MICRO/NANO ROBOTICS

Topic Editor-in-Chief:
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Qingsong Xu, University of Macau, China
Li Zhang, Chinese University of Hong Kong, China

Currently, my biggest challenge is... to have sufficient focuses on all important aspects of my job. Especially, I hope to devote as much time as possible to work with my research team while being active in teaching, working with the research community and other duties. It is very important to me to keep hands-on in research, and the challenge is obviously the available time.

SCOPE AND TOPICS:
Micromanipulation and microassembly
Nanomanipulation and nanoassembly
Biomanipulation and bioassembly
Microfabricated small scale robots
Mobile micro- and nanoscale robots
Bio-nanorobotics
Micro- and nanopositioning
Micro- and nanomechatronics

HUMAN ROBOT/MACHINE INTERACTION, AI IN ROBOTICS

Topic Editor-in-Chief:
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Hagen Lehmann, Italian Institute of Technology, Italy

AI IN ROBOTICS SCOPE AND TOPICS
AI methods for Robotics
Robot Learning and Ontogeny (developmental robotics, neural networks, skill learning systems)
Social Robotics and Social Learning
Sensorimotor Organization and Action (sensorimotor self-organization, active perception)
Behavioral and Cognitive Architectures
Evolutionary Robots
Self-*Robotics (self-reproducing, self-(re)configuring, self-maintaining, self-repairing, self-producing, self-organizing, swarm robotics)
Awareness and Experience in Robots
Verbal / Non-verbal Interaction and Contingency (facial/speech interaction, prosody, proxemics, kinesics)
Affect, Motivation and Volition in Robotics
Robot Embodiment and Design Niches
Experiential Intelligence: Temporally Extended and Narrative Intelligence in Robots
Enactive Systems
Language and Abstraction in Robotics
AI for Humanoids and Non-humanoids
Skillful Manipulation and Temporal, Spatial, Linguistic Intelligence in Robots
Curiosity-based, Context-aware and/or Purpose-aware AI in Robots
Cognitive Systems
Emergent Interactions
Constructive AI Demonstrations
Bio-mimetic and Bioinspired AI Robotics
Robot Instruction
Self-structuring Morphologies

HUMAN ROBOT/MACHINE INTERACTION SCOPE AND TOPICS
Human Robot Interaction
Human Machine Interaction
Rehabilitation Robotics
Sociable Robots and Robots as Social Mediators
Service Robotics and Design Niches
Robotic Pets and Robot Companions
Long-term HxI
Ambient Intelligence for HxI
Physical, Cognitive, and Reality Augmentation
Learning with and from Humans (perceptual abstractions, skills and language)
Human/Robot/Virtual-Agent Mixed Groups
Autobiographic and Narrative Intelligence
Robot Culture
Initiating, Maintaining, Repairing Human-Robot Interactions, Dialogues, and Joint Activity
Human-Robot Interaction in 'Forms of Life'
Social Robotics (programming by demonstration, imitation learning, individualized social intelligence)
Physical and Cognitive Ergonomics (respecting Human Wholeness in optimizing fitting Cyb- to Org)
Neural Control, Communication and Interfacing
Cognitive and Physical Prosthetics
Constructive Examples of HxI Systems
Biomimetic and Bio-Inspired HxI

BIOINSPIRED ROBOTICS

Topic Editor-in-Chief:
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The University of Maine, USA

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MinJun Kim, Drexel University, USA
Jinsong Leng, Harbin Institute of Technology, China
Hoon Cheol Park, Konkuk University, Korea
Claudio Rossi, Technical University of Madrid, Spain
Xiaobo Tan, Michigan State University, USA

Currently, my biggest challenge is... to write a number of disclosures for a number of original patent ideas in biomedical engineering and get them ready for submission to US patent office. However, I simply do not get the time necessary to spend on completing them and this has become a big challenge.

SCOPE AND TOPICS:
Bio-inspired Robotic Artificial Muscles
Bio-inspired Swimming Robots
Bio-inspired Flying Robots
Biomimetics, Bionics and Cybernetics
Bio-inspired Autonomous Robots
Bio-inspired Entomological Robots
Bacteria, Cell and Virus-inspired Microbots and Nanobots
Bio-inspired Companion Robots

ROBOT SENSORS AND SENSOR NETWORKS

Topic Editor-in-Chief:
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Associate Editors I work with:
Yifeng Zhou, Communications Research Centre, Canada
Yuhao Wang, Nanchang University, China
Suyoung Chi, Electronics and Telecommunications Research Institute (ETRI), Korea
Martin Smith, Middlesex University London, UK

Currently, my biggest challenge is to... develop an information fusion approach for multiple UAVs that can combine different sources of information in a consistent and intelligent way for remote and environmental monitoring.

SCOPE AND TOPICS:
Robot Sensors
Smart Sensors
Sensor Fusion
Vision Sensors
Force Sensors
Tactile Sensors
Torque Sensors
Range Sensors
Haptic Sensors
Acoustic Sensors
Sonar/Radar/Laser
Sensor signal processing
Target tracking and identification

Sensor Networks:
Sensors on Distributed Mobile Platforms
Wireless Sensor Networks
Sensor and Information Fusion
Collaborative Robots
Swarm Robotics
Unmanned Aerial Vehicles
Unmanned Ground Vehicles
Intelligent Vehicles
Connected Vehicles

HUMANOID ROBOTICS

Topic Editor-in-Chief:
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Lorenzo Natale, The Italian Institute of Technology, Italy
Liliana Rogozea, Transilvania University of Brasov, Romania
Bram Vanderborght, Vrije Universiteit Brussel, Belgium
Hanafiah Yussof, Universiti Teknologi MARA, Malaysia

Currently, my biggest challenge is...
(I am) working on various multidisciplinary R&D tasks and the use of electroactive materials [http://ndeaa.jpl.nasa.gov/]. These tasks have applications to various fields including planetary exploration, medical treatment and surgical tools, underground drilling, and health monitoring of systems in the field.

One of the areas that I am trying to propel forward is the development of electroactive polymers (EAP), also known as artificial muscles. At the current time, the biggest challenge that I see is - the ability to use these materials to perform robotic functions that emulate the human muscles.

In an effort to promote worldwide development towards realizing the potential of EAP materials, I posed in 1999 an armwrestling challenge [http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-armwrestling.htm]. The challenge is to developed an EAP activated robotic arm that wins against human in a wrestling match and the icon of the challenge is shown in Figure 1. Choosing to focus on armwrestling with a human was done in order to have the human muscles as a baseline for performance comparison. Success will allow using EAP materials to improve many aspects of our life including the development of effective implants and prosthetics, active clothing, realistic biologically inspired robots as well as fabricating products with unmatched capabilities and dexterity that are currently imaginable only in science fiction concepts.

On March 7, 2005, I held the first armwrestling match with a human and it was part of the EAP-in-Action Session of the SPIE's EAPAD Conference. Three robotic arms wrestled against a 17-year old high school female student and the student won (Figure 2). In the following year, I held a 2nd contest and rather than wrestling with a human opponent, the arms performance was measured and the results were compared. A measuring fixture was developed jointly by individuals from UCLA and members of my Group at JPL. The fixture was strapped to the contest table and the EAP actuated arms were tested for speed and pulling force. To establish a baseline for performance comparison, the capability of the same female student who wrestled in 2005 was measured first and then the three participating robotic arms were tested. The tests showed two orders of magnitude lower performance of the arms compared to the student.

The current issue is that the available EAP actuators for use in robotic systems are still significantly weaker in force and operation speed compared to humans. Once sufficient advances are made in EAP capability, a professional wrestler will be invited for a human/ machine wrestling match.

Figure 1: Grand challenge for the development of EAP actuated robotic systems.

Figure 2: An EAP driven arm made by students from Virginia Tech and the human opponent, 17-year old student.

SCOPE AND TOPICS:
Humanoids and Humanlike Robots
Exoskeletons and Prosthetics
Humanoid Perception, Cognition and Recognition
Humanoids Related Ethics

CLIMBING AND WALKING ROBOTS

Topic Editor-in-Chief:
Manuel Armada
Centre for Automation and Robotics – CAR (CSIC-UPM)

Currently, my biggest challenge is... the experimental evaluation in field conditions of a six legged locomotion robot equipped with five degrees of freedom manipulator and a complex sensing system for the detection, identification and removal of anti-personnel land mines.

Topic Editor-in-Chief:
Christine Chevallereau
CNRS, Ecole Centrale de Nantes, France

Currently, my biggest challenge is... to test an original approach of walking control that insures the self-stabilisation of walking on a robot prototype Roméo from Aldébaran.

Associate Editors we work with:
Yannick Aoustin, CNRS University of Nantes, France
Karsten Berns, Technical University of Kaiserslautern, Germany

SCOPE AND TOPICS:
Climbing Robots
Walking Robots
Biped Robots

MOBILE ROBOTS AND MULTI-ROBOT SYSTEMS

Topic Editor-in-Chief:
Nak-Young Chong
Japan Advanced Institute of Science and Technology, Japan

My biggest challenge I have faced over the years at JAIST was how to balance research, teaching, administrative duties, and editorial commitments. From the spring 2015 semester, I am taking a one-year sabbatical and a visiting position at CMU to work on books and explore new frontiers in robotics and artificial intelligence. I am thinking about launching a new project combining information-theoretic approaches with the manipulation planning problem. I further expect to meet new people and be exposed to new experiences and ideas during my sabbatical.

Topic Editor-in-Chief:
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Spanish Council for
Scientific Research (CSIC),
Spain

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Raj Madhavan, University of Maryland, USA
Lino Marques, University of Coimbra, Portugal
Fabio Morbidi, INRIA Grenoble Rhône-Alpes, France
Lorenzo Sabattini, University of Modena and Reggio Emilia, Italy
Antonio Sgorbissa, University of Genoa, Italy
Elio Tuci, Aberystwyth University, UK
Wonpil Yu, Electronics and Telecommunications Research Institute, Korea

SCOPE AND TOPICS:
Wheeled Mobile Robots
Path Planning and Navigation
Surveillance and Exploration Robots
SLAM
Multi-Agent Robot Teams
Distributed Algorithms for Multi-Robot Coordination
Modular Robotics
Swarm Robotics
Mobile Sensor Networks

THE INTERNATIONAL JOURNAL OF ADVANCED ROBOTIC SYSTEMS (IJARS) IS OPEN FOR SUBMISSIONS AND WELCOMES YOUR SCIENTIFIC PAPERS.

TO SUBMIT YOUR PAPER, PLEASE LOG INTO THE EDITORIAL MANAGER.

COLLABORATIONS AND CONFERENCE ATTENDANCE

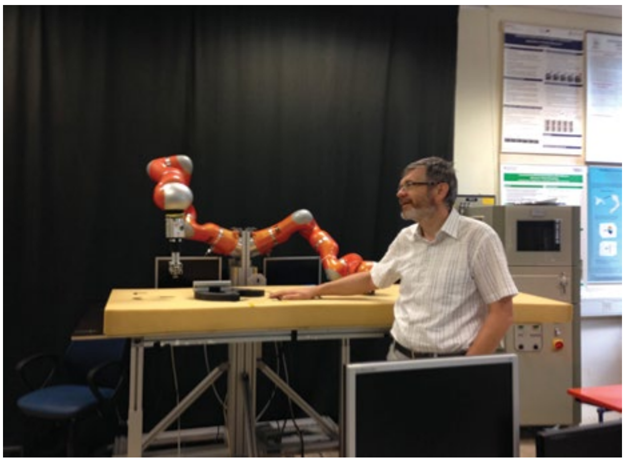
For a second year in a row, the selected IJARS Editorial Board members have participated as judges in Robotics Business Review Game Changer Awards. The following editors participated as judges:

Prof. Amir Shapiro
Dr. John-John Cabibihan
Dr. Raj Madhavan
Prof. Henry Leung
Dr. Loredana Zollo

The successful partnership with Robotics Business Review continues and we hope that it might be our Board members who will be the first to recognise and reward individuals and companies that prove to be the games changers in robotics in the years to come.

For those who have not heard of it yet, the ROBOHUB is a non-profit online communication platform that brings together experts in robotics research, start-ups, business, and education from across the globe. The RoboHub team has started hosting the selected IJARS content and this cooperation is another mean of presenting the journal's collaborations and milestones it has or it is about to achieve. It is our pleasure to be engaged with such content provider.

The IJARS team has continued to attend the International Conference on Robotics and Automation as a flagship conference in robotics. With a venue in Hong Kong, ICRA2014 has given the team members the unique opportunity to meet in person with some of the collaborators from the first decade of the journal's existence. They shared with us their opinion and insights about the journal, its projects and publishing process which allows us to improve and grow in terms of quality and author/editor support. It was a pleasure and a privilege to be in the company of such experts, to discuss all these subjects with them. We look forward to the forthcoming gatherings!



In June 2014, the IJARS team visited JOZEF STEFAN INSTITUTE in Ljubljana, where we were met with hospitality by Prof. Jadran Lenarcic and Dr. Leon Zlajpah. Dr. Zlajpah was kind to show us around the Institute. We also had the chance to attend the ARK (ADVANCES IN ROBOT KINEMATICS) SYMPOSIUM where we promoted the journal, met with some longtime collaborators and established new connections.

YOUNG RESEARCHER INITIATIVE

At the end of 2015, the International Journal of Advanced Robotic Systems plans to engage in a new initiative – the one of supporting young researchers, whether PhD or post-doctoral students. The youth is the driving force, not only in the robotics but in all scientific fields. The young researchers starting their careers need recognition and support to present their ideas and results in the best possible way. We are convinced that there are bright geniuses among these young minds that will set new postulates in robotics. IJARS has been and will continue to be actively engaged in advocating their attempts to achieve their career goals. All details concerning the young researcher initiative will be announced in the second half of this year via our newsletters, social media and homepage. In the meantime, we present you the interview with one of such young and successful roboticists.

YOUNG RESEARCHER INITIATIVE

INTERVIEW YOGESH GIRDHAR

Dr. Girdhar is Devonshire Postdoctoral Scholar, and FQRTN Postdoctoral Fellow at Woods Hole Oceanographic Institution, in the Applied Ocean Physics & Engineering Department.

Yogesh Girdhar received his BS and MS from Rensselaer Polytechnic Institute in 2005, where he was awarded Paul A. McGloin prize for most outstanding academic achievement in Computer Science. He received his PhD from McGill University in 2014 with thesis title "Unsupervised Semantic Perception, Summarization, and Autonomous Exploration for Robots in Unstructured Environments", which received the Honorable Mention for CIPPR Doctoral Dissertation Award. Yogesh's research interests are in the algorithmic challenges that lie on the intersection of field robotics, machine learning and computer vision.

What are the biggest challenges in pursuing a PhD degree?

No matter how good of a researcher you are, during a PhD you are going to face some failures. These failures could be anything from a rejected paper, or not making progress fast enough. Ability to constructively handle these failures, and keeping your morale high is, I think, an important trait of a successful PhD candidate. There is a light at the end of the tunnel; just keep moving.

How important is to have a good adviser and a supportive research environment?

Finding an advisor with whom you can communicate freely, and who gets excited about your research is important, and will make your life during your PhD much easier. However, an advisor who is good for you might not be good for others, and vice versa.

How does a post-doctoral study differ from a doctoral?

I am a relatively new postdoc, so my opinion on this matter is still developing. During a PhD, the main focus is typically on doing research and publishing papers. As a postdoc, apart from doing research, you are introduced to this new world of grant writing, which is a bit different from doing research. Grant writing process forces you to look at the bigger picture, and also gives you a free pass to daydream about the kind of research you would like to do, which I think is quite fun.

How hard/tempting it was to choose whether to pursue a career in academia or industry after graduation? In your opinion, are the challenges bigger in industry or academia?

I think challenges in industry and academia are equally big, however these challenges are of different flavors. By definition, industry is primarily interested in making money, and there is nothing wrong with that; whereas in academia we are motivated by furthering human understanding by doing original research. To be frank, I have been tempted quite often by a career in industry. However, one has to ask themselves what makes them happy. At the end I think it boils down to money versus intellectual freedom. I choose freedom.

Tell us a bit about your current research.

In broad terms, I am interested in making better exploration robots. To do this first we must give robots the capability to perceive their environment at a higher level of abstraction than low level sensor data. I am working on unsupervised machine learning techniques that discover reoccurring spatio-temporal phenomena in the observed sensor data stream, and then use these discovered phenomena to describe the scene. This learned model of spatio-temporal phenomena can then be used to identify surprising or interesting observations that are hard to describe using the learned model. These interesting observations are then used by the robot to plan a better and more informative exploration path.

We are also using similar algorithms for analyzing, summarizing and exploring existing datasets. Currently scientists who use robots for monitoring and data collection tasks have too much data, and not enough human resources to analyze it all. My research provides these scientists with tools to sift through large amounts of data (especially image data) that has been collected by the robots.

What inspired you to decide to work in Woods Hole Oceanographic Institution?

WHOI is a great place to deploy the kind of algorithms that I am interested in developing. WHOI's primary mission is to study the oceans, about which we currently know very little. It is notoriously hard to work in the oceans, especially deep oceans, and hence there is a strong need for autonomous exploration robots, which is where I come into the picture. Also, it is probably the only place where I could work on developing my algorithms, deploy them in the field, and then collaborate with marine biologists and oceanographers to analyze the results.

You work in a specific environment where the research is partially done outside the lab. How is your work distributed? Do you do most of the research in the field?

Currently I am spending 2-3 months in a year out in the field with the robots. The remaining time I am in the lab working on improving the algorithms, and building robots. Being on a modern ship means I can pretty much carry on my research work as usual, even when I am out in the field.

Do you think that conducting research in this way is stimulating and more effective? Are there any downsides?

Testing your algorithms in real extreme environments is a great way to instantly get a reality check on what works and what does not. Moreover, seeing your robots working in the field is a very satisfying experience, and you get to travel to all kinds of exotic locations. The downside is that it takes a lot of effort and resources to do this kind of research work.

In the future, where do you see the applications of your research?

The kind of algorithms we are developing are applicable to many different kinds of data , and not just the data collected by a robot. In particular I would like to use them to analyze and understand films, in the context of their genres. Some preliminary experiments that I have done in collaboration with artist Misha Rabinovich have shown promise of success in this direction. I would also like to apply the exploration and monitoring robots that we are developing to assists biologists and ecologists in studying and preserving forests and other ecosystems.

Lastly, do you have a certain goal to achieve as a roboticist, no matter how far-fetched it might seem from today's technological point of view?

I don't have a specific goal in mind, but a direction to move forward in. I would like to continue to work on algorithms that can extract meaning and underlying structure from the sensor observations of a robot. Through the use of such techniques I envision the exploration robots of the future to be able to automatically form new scientific hypothesis, and collect data to support or disprove them. We would need robots with such capabilities if we were to send them on exploration missions to distant planets, where direct remote operation will not be possible.

GUEST CONTENT EDITOR

In the abundance of information and novelties, it is sometimes hard to keep up with all the relevant and interesting news. The IJARS team wanted to engage someone from the robotics field who would discern the most important and arresting content that would be presented in one place. The ice-breaker for this task was **Dr. Jürgen (Juxi) Leitner**, a post-doctoral researcher currently affiliated with the Australian Centre for Robotic Vision. This young roboticist has selected the series of articles and newspieces that, in his opinion, roundup the first half of 2015. You can read through his selection on our homepage, under News tab where we will regularly be hosting the selection of other Guest Content Editors.

Jürgen Leitner,
Australian Centre for Robotic Vision,
Queensland University of Technology, Australia

Jürgen "Juxi" Leitner is a post-doctoral researcher at the Australian Centre for Robotic Vision working on combining visual information with robot actions. Before joining the Queensland University of Technology (coordinator of the centre) last year, he pursued a PhD at the Dalle Molle Institute for AI and the Università della Svizzera Italiana in Lugano, in machine learning for humanoid robots. He holds a Joint European Master Degree in Space Science and Technology. His background includes working in computer science, vision, machine learning and robotics in various labs including one year working for the European Space Agency.

To keep up with IJARS's other multimedia resources and latest news, you can follow us via our social media accounts on Twitter and LinkedIn.

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VIDEO SERIES

IJARS Video Series is a project initiated with a vision of presenting the latest robotics research and applications novelties, as well as personal overviews on the current state of robotics by some of the most prominent professionals worldwide, not only in a form of journal articles, but also through other freely accessible media.

The recorded videos are available at our web page under Videos tab and on the International Journal of Advanced Robotic Systems (IJARS) **YouTube channel.**

2014/2015 VIDEOS:
Peter Corke, Queensland University of Technology, Brisbane, Australia
Interview

Robert Riener, ETH Zurich University Hospital Balgrist, University of Zurich, Switzerland
Novel Robots for Gait and Arm Rehabilitation (Lecture)
Cybathlon 2016, The Championship for Robot-Assisted Parathletes (Lecture)

Joydeep Biswas & Brian Coltin, Carnegie Mellon University, CORAL Research Group (Manuela Veloso), USA
Interview

Giorgio Metta, Italian Institue of Technology, Italy & University of Plymouth, UK
iCub Philosophy, Some History & Recent Results (Lecture)

Fabio P. Bonsignorio, The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy
New AI and Robotics (Lecture)

Francesco Nori, Italian Institute of Technology, Italy
Complete Force Control in Under-actuated but Constrained Mechanical Systems (Lecture)

Massimiliano Zecca, Loughborough University, UK
Human-Robot Emotional and Musical Interactions (Lecture)

Bruno Siciliano, PRISMA Lab, Universita degli Studi di Napoli Federico II, Napoli, Italy
Aerial Manipulation (Lecture)

Gregory Chirikjian, Johns Hopkins University, USA
Lecture

We invite readers to regularly check the videos page for the upcoming new videos.

WOMEN IN ROBOTICS

Ada Lovelace Day marked the start of yet another IJARS project – WOMEN IN ROBOTICS. With a wish to actively work on supporting the research efforts of numerous female robotics professionals, we appointed three female ambassadors for this initiative and sent a call for papers, being convinced that the knowledge and results contained in the articles promote the best the work of researchers, be they male or female.
The journal has received a number of submissions which are currently under review. Once this evaluation process is finished, our ambassadors will select the best papers among the accepted ones, based on the reviewers' comments and the quality of the presented research. The winning authors will receive waivers for their submissions and the printed edition of the Best Papers Collection.

THE IJARS WOMEN IN ROBOTICS AMBASSADORS ARE:

Dr. Amy Loutfi, University of Örebro, Sweden
(Photo Credits: University of Örebro, Photographer: Ulla-Carin Ekblom)

Dr. Nina Robson, California State University Fullerton, USA
(Photo Credits: California State University Fullerton, Photographer: Matt Gush)

Dr. M. Bernardine Dias, Carnegie Mellon University, USA
(Photo Credits: Carnegie Mellon University)

They have supported this project not only through their engagement as judges in charge for selecting the winning papers, but through sharing their stories and inspirations which you can read on the IJARS Women in Robotic homepage.

WOMEN IN ROBOTICS

INTERVIEW
PROF. RUZENA BAJCSY

Dr. Ruzena Bajcsy is a Professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley, and Director Emerita of the Center for Information Technology Research in the Interest of Science (CITRIS).

Ruzena received a Master's and Ph.D. degrees in electrical engineering from Slovak Technical University in 1957 and 1967, and an additional Ph.D. in computer science in 1972 from Stanford University. She was previously Professor (and Chair) of Computer Science and Engineering at the University of Pennsylvania, where she was Director (and founder) of the General Robotics and Active Sensory Perception (GRASP) Laboratory, and a member of the Neurosciences Institute in the School of Medicine. She has also been head of the National Science Foundation's Computer and Information Science and Engineering Directorate. Dr. Bajcsy is a recipient of honorary doctorate degrees (the University of Pennsylvania, University of Ljubljana and KTH, The Royal Institute of Technology in Sweden), many honors and distinguished awards (Benjamin Franklin Medal for Computer and Cognitive Sciences, Anita Borg Technical Leadership Award, ACM Distinguished Service Award...) and has served on numerous advisory boards and committees. Her current research areas include artificial intelligence; biosystems and computational biology; control, intelligent systems, and robotics; graphics and human-computer interaction, computer vision; and security.

When speaking about women in robotics, one name is not to be omitted. That is Prof. Ruzena Bajcsy, a robotics icon with remarkable both life and career stories. The IJARS team had the privilege of hosting an interview with Prof. Bajcsy and we are very happy to share it with you, dear readers.

You have been active in engineering (both electrical and computer) for more than 50 years. Based on your experience and tutoring, what would, in your opinion, be the characteristics of a good engineer?

What is a good engineer? A person who is willing to learn all his/her life both new mathematics, new devices, new algorithms and build systems.

Coming from the former Czechoslovakia to the United States back in the 1960s you have mentioned that you did not only encounter a different political system, but the educational one as well. To adapt to new educational approaches you probably had to develop new set of skills and this was surely a venture. The student mobility today is relatively high and, although some differences remain, it is easier to adapt to the new surrounding. Do you feel that stronger encouragement of student/research staff mobility should be more financially strengthened? Would this play a vital factor in reducing the disproportion between the number of female and male engineers?

Student mobility is very important. Especially now when we are all connected. Science and engineering are international. I do not think that the international nature of science/engineering will be a factor which decides the proportion between men and women. These factors, in my view, are more historically and culturally determined.

WHAT I AM TRYING TO DO IS TO SHOW TO STUDENTS (BOTH MEN AND WOMEN) HOW SATISFYING AND EXCITING THE WORK IN ROBOTICS IS.

In your work you have combined the knowledge from your field with that from other scientific (sub)fields such as medicine (the 3D atlas of the brain), biochemistry, psychology, and even art in your teleimmersion project. How important is the interdisciplinary approach in robotics? Will it play a more important role in the future?

Yes, the new discoveries and inventions will come from exploring the boundedness between different disciplines. Today biologist use quite a bit of physics, mathematics, engineering. Similarly, engineers are motivated by advances / understanding of biology, psychology and social sciences.

As head of National Science Foundation's Computer and Information Science and Engineering Directorate you managed $500 million annual budget. How challenging is to try to predict what will be the driving force of research in, let's say, five to ten years from now? Because allocating budget for a specific research now means that the results will be probably visible in a couple of years. And these results should prove important and justify the investment?

When you are in a position as I was at the National Science Foundation you must be willing to learn the broad advances in the discipline that you represent. It is not good enough to be an expert in your specific area, in my case robotics. The acquired breadth complemented with some intuition/common sense can give you ideas what will likely be the future advances. Of course, discoveries are so unpredictable the government/funding agencies must be open-minded when deciding what to support and where to put investment.

The economic crisis we still suffer today has forced countries to cut down budgets for science and education. Will this set back the quality of research in the long run? Is financing research from industry perhaps a problem-solver?

Yes, government funding for research and education is critical for future innovation. Industry has a very short horizon hence cannot afford a long-range research.

You were the first (or the only) woman many times during your lifetime: the first in Slovakia with a PhD degree in electrical engineering, the first woman to head NSF's Computer and Information Science and Engineering Directorate, a founder of GRASP Lab at the University of Pennsylvania. Luckily, there are very few positions left today where women are appointed for the first time. In your opinion, how could women be encouraged to choose a career as roboticists?

I am not sure how to encourage women into robotics. What I am trying to do is to show to students (both men and women) how satisfying and exciting the work in robotics is. I am especially trying to show how robots and robotic technology can help people and society - consider robots helping disabled, both physically and cognitively, children, adults and elderly.

How important are good and supportive mentors when it comes to motivating young girls to pursue a career in engineering? Should the promotion of female engineering role models be strengthened?

Yes, we need to get away from the perception that robotics is not feminine as it was in my youth. Girls and women can do anything when they put their mind into it.

Who was your role model when you were starting your career?

Both my parents were a model in different ways. My father was an engineer and I wanted to be like him. My mother was a professional who believed that woman should not get married just to be supported. And Marie Curie was considered a model of a dedicated scientist.

GOVERNMENT FUNDING FOR RESEARCH AND EDUCATION IS CRITICAL FOR FUTURE INNOVATION.

You have often mentioned in your interviews the "screwdriver theory" - that women tend to shield away from engineering because having to work with screwdrivers is not feminine. But you have also emphasised that a career in computer science is ideal for women because it offers a great deal of flexibility. These two remarks capture very well the ambivalence women face today when choosing their careers. What would be the pros and cons of working as a roboticist?

There are (as often is) PROS and CONS to work in robotics.

The PROS: As I explained above robotics deals with building complex systems (hardware/software) interacting with people and very varied environments which are both challenging and rewarding. The systems that we build serve societal needs in many respects. This technology for the first time in our history is complementing the human capability not only at the physical level but also on a cognitive level. This raises some concerns (taking away white-collar jobs) but I believe we should be able to resolve this wisely.

CONS: The dilemma that the people who work in robotics face and that is no different than in any other profession: is how to manage professional life with family life.

What have we, as a humanity, learned about ourselves by building robots? And finally, what did you learn about yourself through your research?

On the physical level, what are our limitations, how to be stable when standing, walking, how to keep our flexibility and endurance.
On a cognitive level - the same - our memory is limited, so is our perception. Yet we are much more universal in our capabilities than machines/robots.

ROBOTS IN INDUSTRY

THE ROBOTS ARE ALREADY AMONG US

AN OVERVIEW OF THE LATEST TRENDS IN APPLICATION, POPULARISATION AND SOCIETY IMPLICATIONS OF ROBOTS IN OUR AGE

The ever-popular topics of robots vs men, robots and men, robot-men have been flaming up discussions and opinion sharing in diverse domains that go well beyond the robotics conferences and forums just to land in TV talk shows, people's living rooms, or late night chitchats among peers during afterwork dinners or drinks. If once, not so long ago, the science of robotics was considered a domain shared by academia and industry, and pertaining only to those with institutional credentials and a formal education in engineering and technology, there has been a 180 degree shift where robotics is now part of each individual's everyday reality, regardless of his or hers willingness or unwillingness to admit so.

With the introduction of robot applications in various industries, starting from the more traditional ones such as agriculture, automobile, construction, manufacturing, military, mining, and transportation industry where robots have been deployed for decades, the more recent applications have concerned new industries including healthcare, entertainment, hazardous environments, laboratories in general and the personal home domain.

With this sudden shift and with the fast spreading trend of introducing robotic systems to so many service industries and one's personal life in the form of utilities, the question raised by both professional communities and the layman is the same, and it's a repetitive one: how does the robot change our lives?

US HUMANS AND THEM ROBOTS

The general concern of today's modern society lies in the impact of robotic systems on employment trends, the effect of robots on interpersonal relations and the implication of AI and its development on current laws and regulations applied to us, humans. But is it really a matter of us humans against them robots and a newly started battle for survival in and for this world, as many seem to perceive it? Or is it rather a great opportunity to improve life's quality with the aid of amazing technological advancements that spur economic growth, better services to people in general and a whole new cluster of creative opportunities to fulfill one's life?

Whatever one's answer to the question above is, seems like everyone is in it for the discussion, hence proving that we are well beyond accepting robots in industries and private domains, as these are already here to stay.

ROBOTS IN INDUSTRIES

How much, how many?

The topic of robots and their employment in industries would not be so interesting it if there was no proof of a massive and rapid growth of robotic applications spanning from more traditionally robot-related industries such as manufacturing, agriculture and so on, to the new ones (for example, the entertainment industry). When thinking of the robot application growth in numbers within these diverse industries, the following most recent statistics might not come as a surprise (or will it)?

The International Federation of Robotics (IFR) stated that about 225,000 industrial robots were sold in 2014, 27% more than 2013's best-year-ever record. The same kind of trend is to be applied to service robotics where 4 million domestic robots were sold in 2013 and projections say that these number will reach a whooping 31 million for the period between 2014 and 2017.

According to TechNavio (a British technology research company), the global exoskeleton market within military, factory and rehabilitation/healthcare industries will grow at a 72.5% (CAGR - Compound Annual Growth Rate) until 2019. The global pharmacy automation market (central-fill systems, telehealth, robotic prescription dispensing, automated kiosks) will see a 7% (CAGR) growth in the next four years. The global mobile robotics market (in aerospace, defense, automotive, warehouse, healthcare, energy, agriculture and mining industries) is predicted to grow 12.63% (CAGR) until 2019, while the US residential robotic vacuum cleaner market (iRobot, LG Electronics, Monaural, Neato Robotics and Samsung) will reach a 6.43% (CAGR) growth until the end of the decade. Furthermore, Wintergreen Research (a Boston forecasting company) projects a growth of 34.3% (CAGR) of commercial drone applications over a period between 2015 and 2021, and Strategic Defence Intelligence (British company) predicts a 5.66% (CAGR) growth of UCAVs (UCAV - an unmanned combat aerial vehicle) until 2025. Finally, the medical robots market will be growing at a CAGR of 16.1% from 2013 to 2018 while the consumer and office robots (home cleaning, remote presence and home entertainment robots) will see an increase at a 17% (CAGR) from now until 2019. [1]

Looking at the various projections and statistics, the application of robots in industries is about to reach an unprecedent speed of growth and wide-use well before the end of the current decade. And that is a fact.

The academia and/or industry affair

The constantly growing interest in robotics research and application development and deployment has lead to a new era where newly developed technologies are introduced to new markets, as stated previously and proven by the most recent data on robotic application growth. A large number of these technologies are born within companies who run their in-house research labs. However, it is also true that novel ideas that brought technologic innovations spurred from academic research domains across the world. Many roboticists as well as academia representatives agree that to apply and deploy in the best possible way the research output done both in industry and academia, there is a need to bridge the gap between these two types of communities, establishing fruitful collaborations that would benefit both parties. However, looking back at some of the efforts made until now and regarding the trasfer of idea and research output between academia and industry and vice versa, the main issue seemed to be finding a common ground between the two, as industry’s interest lies in the profit and its necessities in the short term, while academia focuses on a long-term view.

In recent years there has been a proof that the trend is changing as more and more initiatives are taken to connect the two sectors in an effort towards faster technological transfer and introduction in various markets.

Collaborative projects such as NASA’s Robotics Alliance Projects, the European ECHORD++ project, the Robotics Collaborative Technology Alliance or the Globasl COE Program are excellent examples of a new trend towards better connecting the two key players involved in today’s robotics innovation and advancement fields.

SOCIAL IMPACT OF ROBOTICS

Ready or not?

Going back to to the fuelling discussion of how will robots impact today’s society, especially when it comes to shifts in employment opportunities and the way we correlate to each other, as Singularity Hub smartly suggests, we already have entered an era where exponentially growing technologies, among them AI and robotics, greatly disrupt the way the majority of people work and earn a living.

Whether you think that automation in various industries or service robots and AI will take away from humans what the humans have been put on this earth to do, or you prefer to look at our technological era as a blessing yet to reach its best, the changes in how we perceive what is around us have begun a long time ago when TVs were introduced in every living room and the telephone shifted the way we communicate. And wasn’t that the turn towards better things to come? So is robotics.

Ray Kurzweil recently forwarded a very enlighting vision of how robots will liberate the humankind rather than imprison it in the years to come: *“Automation certainly won’t mean the death of human work. In the best of all possible worlds, it will mean an end to work that is unfulfilling. For some that would mean time spent creating and inventing, for others that might mean a lot of time spent playing with all those new creations and inventions, which is kind of the point.*
Additionally, technology will only accelerate our capacity to pursue diverse of interests. “[2]

[1] *Numbers obtained from http://www.therobotreport.com*

[2] *The End of Meaningless Jobs is a Win for Us All, obtained from singularityhub.com*

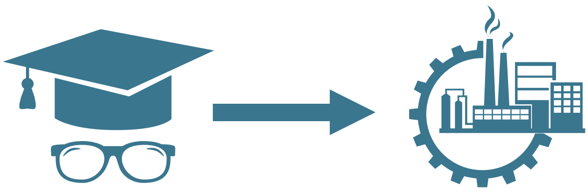
ROBOTIC TECHNOLOGY IS NOT ONLY THE TECHNOLOGY OF TODAY, IT IS FOREMOST THE TECHNOLOGY OF TOMORROW. TO BRING IT TO OUR HOMES AND LIVES, THE ACADEMIA AND INDUSTRY HAVE TO TEAM UP. WITH THE INCREASING NUMBER OF ROBOTIC START-UP COMPANIES AND THE GROWTH OF EXISTING ONES, THE NUMBER OF PEOPLE WORKING IN THE INDUSTRY WILL SURELY GROW EXPONENTIALLY. THE INDUSTRY AND ACADEMIA ALREADY CO-OPERATE AND THE KNOWLEDGE IS TRANSFERRED FROM THE LABS TO THE OFFICES AND VICE VERSA.

The IJARS team wanted to explore the views on this subject from different perspectives. We have, therefore, interviewed people who have either transitioned from academia to industry, started their career in industry (and remained there ever since), or who are conducting research in both, academia and industry.

ACADEMIA AND/OR INDUSTRY?

INTERVIEW
DAVID ISRAEL GONZÁLEZ AGUIRRE

Dr. David I. González Aguirre is currently a full time researcher at Intel Labs in Hillsboro, Oregon, USA.



Dr. David I. González Aguirre has conducted research as a post-doctoral researcher within the Institute for Anthropomatics, Karlsruhe Institute of Technology (KIT). He received his Ph.D. degree with honors (summa cum laude) from the Karlsruhe Institute of Technology (KIT) in 2013. He holds a master of science from the National Polytechnic Institute in Guadalajara, Mexico (CINVESTAV) 2006. His major research interests are sensor fusion, humanoid robots and computer vision.

How difficult would you say it is to transition between industry and academia? Which kind of transition (from academia to industry, industry to academia, or between academic institutions) would you define more difficult for a robotics professional?

Based on my personal experience, I would affirm that a transition between industry and academia requires more effort than moving between academic institutions. This occurs due to various technical and legal aspects:

The technical constrains appear right after you have started the transition process, namely telling your boss you have new plans! The technical implications involve not only the current project you are working on, but also those you contributed and those that are part of the standard systems or demos in the lab.
In most cases, as professional researcher you want to keep not only a good image with your boss but also with your peers in order to collaborate in the future.
This “do not burn your bridges” can cost a lot of time and energy since you have to do your normal job while training someone or documenting the code you created.

The legal aspects imply that you cannot simply take your know-how, source code or other forms of intellectual property and put them into your new project or job. This is particularly interesting when you consider that this rule applies even to standard libraries you usually integrate in your projects.
Moreover, the legal overhead can be very stressful when considering changing the country, continent and language.

Despite of the hard work that this transition implies, it is a very good experience. You will get to meet new people, places, role models, methods, technologies, etc. You will also be conforted with a new set of collective focuses, skills and values. This is a moment when you feel glad about the skills and knowledge you have acquired along your academic path. This is the point when you really feel proud of your previous labs and universities.

There is this general conception among roboticists that in the US the academia’s focus is on fundamental research, while in Europe there is a lack of academia and industry collaborations resulting in a slower process when it comes to field applications. Would you agree?

I think it is difficult to generalize. By my limited observations from studying and working at the KIT in Germany and now (as a researcher) at Intel Labs in USA, it is easy to notice that the industry in the USA is very interested in what the universities are doing world-wide. I see on a weekly basis diverse presentations of professors doing a lot of applied research and spin-offs. It is natural part of the American mentality and culture to try new ideas without being afraid of failure. In this particular country the people see a lot of value in learning the lesson. In Europe, the high density of well educated people, strong hierarchical organization combined with the co-existence of cultures make it harder to try new ideas and business. I also believe that these differences can be tracked down to the availability of space and natural resources, without even mentioning the historical development processes.

As a robotics professional working in the industry, do you think that academia research is important or there is often no need to team up when designing and building a new technology?

Research is fundamental and irreplaceable. The academia and industry play very different roles. The freedom and diversity in the academia make it possible to find theories and explore ideas which are far from being applied in the everyday situations. This is the right thing to do there. Meanwhile, the industry places its focus on the research which can be delivered to the society in a short term.

THE SCALE AND SCOPE OF THE INDUSTRY IS HUGE COMPARED TO THE UNIVERSITIES.

When technology is transferred from academia to the industry, what are the biggest hurdles to overcome?

In addition to the legal management of the intellectual property, the performance in terms of robustness, precision and running times which in a lab context turn to be simply unacceptable for the industry. Thus, many problems that are already declared as solved or trivial in the academic context need lots of work in both complexity reduction or parallel implementations to cope with the application requirements.

From an industry point of view, would you say that the role of academia is to come up with new ideas, design and innovations while it is the industry's job to make these new technologies viable, profitable and working?

Actually, I would not state this so straightforward. I think the craft of research in general is more like cyclical process where ideas, techniques and technologies flow in both directions. This classical view (where academic research is converting money into knowledge and industrial research the opposite) has lots of counterexamples especially in robotics and artificial intelligence.

You have worked in academia and transitioned to industry; what are the pros and cons of the two in your opinion? How can academia prospect from sending "bright minds" of robotics to industry?

The pros of this transition are:

There are many paths and career models in the industry. Whereas at the universities the path is one way and the risk of not getting a professorship is very high in developed countries.

The scale and scope of the industry is huge compared to the universities. This is usually reflected in your income and responsibilities as well.

In the industry the people work in the same place for a longer period of time. Thus, the know-how and degree of expertise is way higher than at the university which are continuously producing qualified people (who have to leave) over and over. Hence, in the industry you have the chance to work with the super-qualified professionals who are going to stay there as long as the company is producing revenue.

The meritocracy principles apply systematically. Thus, there is a fairer balance between individual output/performance and the soft skills/political engineering.

RESEARCH IS FUNDAMENTAL AND IRREPLACEABLE.

The cons:

You cannot always talk about what are you doing or share the ideas to get advice, receive criticism and valuable feedback from other peers or friends outside the company.

The mindset is not so diverse and people share less of their life with the co-workers.

Your freedom to choose the topic and methodology may not always be there.

Can you think of a project that wouldn't have commercially succeed if there had been no collaborative efforts between academia and industry?

I have not been long enough in the industry to have fully developed product.

ACADEMIA AND/OR INDUSTRY?

INTERVIEW
RICH WALKER

Rich Walker is a Managing Director of the Shadow Robot Company, London, UK.

After obtaining his diploma in Computer Science from Cambridge University, Rich Walker had spent years working in robotics, and now leads the team at Shadow that is developing new robots and new applications for robotics. Apart from being active in developing and implementing European (FP7/Horizon 2020) and TSB/Innovate UK projects, Rich is a member of the TSB's "Robotics and Autonomous Systems" SIG Steering Committee, and an SME member of the EuRobotics Board of Directors.

How difficult would you say it is to transition between industry and academia? Which kind of transition (from academia to industry, industry to academia, or between academic institutions) would you define more difficult for a robotics professional?

I've never tried to move into academia, but lack of a publication record would be the most obvious concern.

There is this general conception among roboticists that in the US the academia's focus is on fundamental research, while in Europe there is a lack of academia and industry collaborations resulting in a slower process when it comes to field applications. Would you agree?

European research funding has been pretty good at collaborations between academia and industry for the last decade, and it's getting better.

Europe has a collective organisation (EuRobotics) set up in 2012 to bring industry and academia together to focus progress on common roadmaps. That has really accelerated progress in this area - it has about 1/3 industrial and 2/3 academic members (out of a total of about 230 members) but is industry led, and formally advises the European Commission on their roadmap.

As a robotics professional working in the industry, do you think that academia research is important or there is often no need to team up when designing and building a new technology?

Creating something new at TRL1 isn't going to happen anywhere except academia. Look at Graphene, for example.

We find that there are parts of development processes where academic thinking and approaches are necessary - for example, scientific testing - and parts where an industrial focus makes more sense - for example, manufacturing prototypes...

The number of robotics companies seems to be increasing every year. Could the developments in industry have a more influential role on the research trends in academia in a near future?

OPEN RESEARCH FUNDING HAS BEEN PRETTY GOOD AT COLLABORATIONS BETWEEN ACADEMIA AND INDUSTRY FOR THE LAST DECADE, AND IT'S GETTING BETTER.

In Europe, absolutely - we provide strong feedback to generate the Multi-Annual Roadmap which feeds into the Strategic Research Agenda. There are also processes to try and align these with roadmap activities in other parts of the world.

When technology is transferred from academia to the industry, what are the biggest hurdles to overcome?

Technology transfer offices at Universities. (Seriously). Unrealistic expectations of how valuable the technology is at that point in time, and how much money is being made from it.

From an industry point of view, would you say that the role of academia is to come up with new ideas, design and innovations while it is the industry's job to make these new technologies viable, profitable and working?

Yes.

What are the pros and cons of working as a roboticist in industry?

Technically, I just manage roboticists, so a little hard to say. However, I would suggest that the most important point is the existence of customers - real people with real problems you are trying to solve. Fantastic motivation.

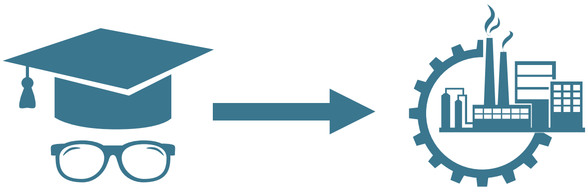
Can you think of a project that wouldn't have commercially succeed if there had been no collaborative efforts between academia and industry?

Um. Nothing off the top of my head.

ACADEMIA AND/OR INDUSTRY?

INTERVIEW
JUR VAN DEN BERG

Dr. Jur van den Berg is currently a researcher/developer at Google[x], San Francisco, California, USA.



Jur van den Berg obtained his PhD from Utrecht University, the Netherlands in 2007. After his PhD, he went to the University of North Carolina, Chapel Hill to do a postdoc. Initially, his plan was to be there for just one year to gain international experience, after which he would take up a position as assistant professor back at Utrecht University. Life in the United States, however, captivated him so much that he changed his plans and stayed a postdoc for another three years, initially at UNC, and later at the University of California, Berkeley. Being a postdoc is possibly the best job on earth; one gets to spend full time on research, without additional responsibilities such as teaching and sustaining a research group. However, being a postdoc is by definition a temporary job, so after being a postdoc for a total of four years, Jur joined the faculty at the School of Computing at the University of Utah in 2011. After a successful three years there, he was recruited by the Google self-driving car project, which Jur considered (and considers) to be the coolest robotics project being undertaken in the world. So he chose to exchange his academic career for the one in industry, which at the time was a somewhat scary decision, but one which he does not in any way regret.

How difficult would you say it is to transition between industry and academia? Which kind of transition (from academia to industry, industry to academia, or between academic institutions) would you define more difficult for a robotics professional?

I have only experienced the transition from academia into industry, so I can only comment on that transition, and not on the reverse one. Even so, I figure that this experience can differ considerably from person to person. First of all, the objectives are different between academia and industry. In academia the goal is to introduce new knowledge and algorithms, where perhaps intricate details and edge cases are not of the essence, whereas in industry the goal is to produce implementations that work, always. So the work that one is doing will have a different focus.

I also found the lifestyle to be very different. This may be different for different people, but my life went from completely irregular to one with a very regular schedule. In academia, I was always either working towards or worrying about the next deadline, whereas in industry I probably work longer days but can be fully off work when at home. In that sense I find working in industry less stressful. On the other hand, I found life in academia to be very romantic: I would for example sometimes get out of bed in the middle of the night because some great new idea came to mind, and not fall asleep until the first paper draft was ready late in the morning. There is a lot of freedom, for instance to travel to conferences and collaborators, and work on topics you can choose yourself. And you can publish under your own name, which I always found to be very rewarding.

I do not think the transition from academia to industry is difficult, but it requires some flexibility. I think it is particularly important to have the right expectations about what the job will look like, and what the responsibilities are.

For the reverse transistion I have no experience. I sometimes hear that the danger is that one loses connection with the research community, and not being up-to-date with the literature.

There is this general conception among roboticists that in the US the academia's focus is on fundamental research, while in Europe there is a lack of academia and industry collaborations resulting in a slower process when it comes to field applications. Would you agree?

No, I would not necessarily agree. Collaboration between academia and industry is too often a buzz-word for policy makers and funding organizations, but my sense is that these are usually "collaborations" in name only. The agendas and goals are often too divergent. To put it simply, academics like to explore fundamental questions, while industry really wants to get something working. I do think that academia and industry are very complementary though, and that there is a lot of collaboration in the indirect sense. For instance, there are many academics that consult for a company, or are hired for a year to focus on a particular industry project. Perhaps more importantly, academics educate the people that companies hire. Also, for fundamental knowledge and algorithms, industry of course heavily uses the academic literature. So personally I think it is a good thing that academia focuses on

PERSONALLY I THINK IT IS A GOOD THING THAT ACADEMIA FOCUSES ON FUNDAMENTAL RESEARCH AND THAT INDUSTRY TAKES A MORE PRACTICAL GOAL-ORIENTED APPROACH.

fundamental research and that industry takes a more practical goal-oriented approach.

As a robotics professional working in the industry, do you think that academia research is important or there is often no need to team up when designing and building a new technology?

Academic research is incredibly important. In fact, I would make the case for fundamental research. My personal experience from working in industry is that I "use" much more fundamental academic research in my daily work than more practical or systems-oriented research. I do personally not believe that there needs to be a forced "teaming up", as academia and industry seem to naturally complement each other.

When technology is transferred from academia to the industry, what are the biggest hurdles to overcome?

I think one of the hurdles is that academic research may not focus on all edge cases, or make simplifying modeling assumptions that turn out not to be very representative of the real world. Nonetheless, the basic framework is often there, and in a way it may perhaps be industry's responsibility (in the context of the complementary nature of academics and industry) to make academic knowledge applicable in the real world. In academia, one is not necessarily rewarded for going through the process of making something work all the time (it wouldn't make for interesting research papers if all special cases and bandaids are discussed). A proof of concept is usually sufficient, and for the purpose of introducing or conveying new insights even preferred.

From an industry point of view, would you say that the role of academia is to come up with new ideas, design and innovations while it is the industry's job to make these new technologies viable, profitable and working?

Yes, I globally agree with this statement. Although "innovation" is a broad term that certainly also applies to the work industry is doing. Pursuing pure fundamental research is often not aligned with industry's immediate goals. On the other hand building large and reliable systems is usually out of scope of a single research group in academia.

You have worked in academia and transitioned to industry; what are the pros and cons of the two in your opinion? How can academia prospect from sending "bright minds" of robotics to industry?

Academia may indirectly benefit from people moving to industry. If robotics companies are successful and let robots tangibly improve people's daily lives, this also makes the academic community look good. More funding may become available as a result, and more students may apply for an education in robotics.

Can you think of a project that wouldn't have commercially succeed if there had been no collaborative efforts between academia and industry?

No industry project in robotics would have succeeded if academia weren't there to educate the people that worked for these industries, or to provide the fundamental knowledge that underpinned these commercial successes. But I can't think of a project where direct collaboration was in fact essential to the commercial success.

ACADEMIA AND/OR INDUSTRY?

INTERVIEW
KAZUHIRO NAKADAI

Prof. Kazuhiro Nakadai is a principal researcher for Honda Research Institute Japan Co., Ltd., and currently holds two visiting professor positions - at Tokyo Institute of Technology and Waseda University.

Kazuhiro Nakadai received a B.E. in electrical engineering in 1993, an M.E. in information engineering in 1995, and a Ph.D. in electrical engineering in 2003, all from the University of Tokyo. He worked at Nippon Telegraph and Telephone and NTT Comware Corporation from 1995 to 1999, and at the Kitano Symbiotic Systems Project, ERATO, Japan Science and Technology Agency (JST) from 1999 to 2003. His research interests include AI, robotics, signal processing, computational auditory scene analysis, multi-modal integration and robot audition. He is a member of the ASJ, RSJ, JSAI, IPSJ, HIS, and IEEE.

How difficult would you say it is to transition between industry and academia? Which kind of transition (from academia to industry, industry to academia, or between academic institutions) would you define more difficult for a robotics professional?

In general, I do not find it difficult to transition between industry and academia, since their purposes are different. In academia, I try to focus on education. Therefore, my highest priority in the university setting is to build a comfortable environment for each student in my laboratory to conduct his/her own research. In industry, however, the main purpose is to complete the current project. The main target of the project has already been clarified and we just work to achieve this target. It is obvious that these two environments have different purposes, making it relatively easy to transition between them.

There is this general conception among roboticists that in the US, the academia's focus is on fundamental research while in Europe, there is a lack of academia and industry collaboration resulting in a slower process when it comes to field applications. What's the situation like in Japan?

Generally, the situation in Japan is similar. Industry does not expect too much from academia except for new ideas, while academics regard themselves as working only for the amount of money they receive.
Due to the divergence of ideas, successful collaboration becomes difficult.
Fortunately, I have successfully collaborated for over ten years with Prof. Okuno of Kyoto University (currently working at Waseda University). This collaboration has continuously produced fruitful results. Actually, it is no exaggeration to say that all achievements in "Robot Audition" proposed by Prof. Okuno and I have resulted from this collaboration.
The reasons for this successful collaboration are twofold. The first is that Prof. Okuno understands the thought processes of a Japanese company since he formerly worked at a company. The second is that Honda Research Institute Japan is compatible with an academic way of thinking, regarding it as the one that leads to innovative technology. In other words, the success of this collaboration is due to a well-established win-win relationship thanks to mutual concessions.

> *INDUSTRY REQUIRES BUSINESS-ORIENTED PROJECT EVALUATION.*

You have backgrounds in both academia and industry. How distinct are the roles of academics and professionals working in the industry in terms of research? What would be the pros and cons of these roles?

As mentioned previously, I believe that the most important role of academia is in education, while the most important role of industry is to complete the current project as a manager and/or researcher.
The advantages of academia include contact with students who provide new ways of thinking, and opportunities to start research projects for which is too early to be explored in industry. The disadvantages include the difficulty of accomplishing goals within about one year due to a lack of human resources. Of course, I am really happy when a basic research project that started in my university laboratory can be applied to research within a company, but this is rare.
The advantages of industry include a financial strength, and easy connection to potential users such as a business division in the company. Industry, however, requires business-oriented project evaluation. Since researchers must pursue efficiency, they tend to be narrower-minded, which is a big disadvantage in industry.
I believe that these two settings are complementary. An ideal situation may be appointments in both settings, enabling researchers to have the best of both. However, the amount of work required from each researcher will be much higher in this case.

When technology is transferred from academia to industry, what are the biggest hurdles to overcome?

I definitely believe that the most important factor is mutual understanding.
Generally, a seed-oriented approach to technology is studied in academia, with a proof of concept requiring only one successful

example. In industry, need-oriented approach is more desirable and the technology must work properly in every expected situation. This gap is sometimes called the valley of death, or the devil's river, and it is difficult to overcome it. Therefore, at an early stage of a collaboration, the academic and industrial researchers should understand what they really want to achieve, and then they should proceed with technology transfer together.

From an academic point of view, how important it is for a new algorithm, design or technology to be viable and working under different conditions and at all times or is the focus mainly about new ideas rather than thinking about their deployment in industry?

I strongly agree that it is important that a new algorithm, design or technology work at any time and under many different conditions, even from the academic viewpoint. A theory is essential, but it is also crucial to design an algorithm based on the theory that properly works in the real environment. Since designing such an algorithm is not always easy, we sometimes discover new findings and new ideas during the process of its implementation.
I believe that many researchers and professors in robotics have similar ideas. That is why I attribute much importance to robotics.

From an industry point of view, would you say that the role of academia is to come up with new ideas, design and innovations while it is the industry's job to make these new technologies viable, profitable and working?

I think so generally, although I am not sure if my thoughts fit within today's society.
In my opinion, researchers in academia should work more on fundamental research since they have such ability. Researchers in industry should have greater knowledge of fundamental research, enabling deeper understanding of the technology developed in academia, and transferring it to industrial settings.
Moreover, I believe that the staff exchange between academia and industry should become more active in Japan. It is difficult to start big projects in academia. The same applies to the emerging research projects in many industrial companies. A greater degree of inter-personal communications can ease these problems, resulting in increased number of innovations in Japan.

AMONG THE PROJECTS REQUIRING COLLABORA-TIONS BETWEEN ACADEMIA AND INDUSTRY IS THE ROBOT AUDITION PROJECT.

Can you think of a project that wouldn't have commercially succeeded if there had been no collaborative efforts between academia and industry?

Among the projects requiring collaborations between academia and industry is the robot audition project. Since this is a new area of research, it is necessary to explore emerging research topics which are difficult to accomplish in industry. If this exploration reveals a promising technology, it can be implemented in our open source robot audition software HARK (Honda Research Institute Japan Audition for Robot with Kyoto University) for verification of the technology and contribution to robotics society.
It is too difficult to continuously maintain open source software like HARK in academia, making industry responsible for its maintenance.
Therefore, both robot audition and HARK have been developed through collaborations between academia and industry.

INTERVIEW
FABIO BONSIGNORIO

Prof. Fabio Bonsignorio is the founder and CEO of Heron Robots as well as an affiliate professor at the Biorobotics Institute (Scuola Superiore Sant'Anna, Italy).

For more than twenty years, Prof. Bonsignorio has worked in the R&D departments of Italian and US companies, such as Elsag-BM in CIM (Computer Integrated Manufacturing), ORSI Automazione, Imation, cooperating with, for example, E&Y and Oracle. He is author and co-author of more than 100 publications in the areas of robotics, cognition and manufacturing systems. Prof. Bonsignorio is interested in foundational and epistemological issues in (embodied) cognition and robotics, while chasing viable real world applications. He is a member of IEEE/RAS, AAAI, CLAWAR, and euCognition. He coordinated the EURON Special Interest Group on Good Experimental Methodology and Benchmarking in Robotics, and is now the coordinator of the euRobotics TG on Benchmarking the Competition, as well as co-chairing the IEEE RAS TC-Pebras. He is the coordinator of the ShanghaiLectures, www.shanghailectures.org.

How difficult would you say it is to transition between industry and academia? Which kind of transition (from academia to industry, industry to academia, or between academic institutions) would you define more difficult for a robotics professional?

I think there is no definite answer. In general, I believe the difference is fading. If you are a professional or a manager in the new or old industrialized countries (and in particular in the 'high-tech' and research intensive sectors, but not only there) as more repetitive tasks in the industry are increasingly delegated to machine intelligence, you are essentially required to be creative, entrepreneurial, and to recognize and anticipate the science and technology trends. And then you have to chase funding and be budget savvy. This is requested from academics too.
There might be, and still are in some places, bureaucratic differences. For example, if you have worked in the industry you might have some personal patents, but your h-index will likely be low. If you have worked in the academia your sales and/or marketing experience will be of a different kind – you need them, anyhow, as we know, in the academia too, if you rely on competitive funding. However, you may have no experience in 'real projects' and 'real management responsibilities'.
Yet in academia, too, you have to be creative, entrepreneurial and ahead of the curve. Consequently, some repetitive tasks are then automated, or delegated (unfortunately sometimes to PhD students).
Apart from bureaucracy and 'old world mindsets' I don't see major obstacles and I also think that the exchange of people is probably quite helpful for both industry and academia.

There is this general conception among roboticists that in the US, the academia's focus is on fundamental research while in Europe, there is a lack of academia and industry collaborations resulting in a slower process when it comes to field applications. Would you agree?

No. In the US, specifically in the Silicon Valley and increasingly in many other 'hot spots' around the country, the research is quite similar in level and scope to the European one. The same applies to the basic research in robotics. At least some institutes in Europe may even have a remarkable competitive edge. If we had a business system like the United States have, our industry and business would become more competitive. This should be a bipartisan priority in the EU politics. The difference is that in the US the high-tech ecosystem (from research to industry, finance, or to institutions) is much more developed and much more open to new players. In the EU the incumbents are more protected and as a consequence less innovative and less 'attractive' for investors, while start-ups are still not particularly welcome or helped, let alone funded (despite the official rhetoric). China seems to pursue a 'silicon valley approach' to technology transfer with a massive role of the public entities, including public venture captial. We should pay more attention to them.

You have background in both - the academia and industry. How distinct are the roles of academics and professionals working in the industry in terms of research? What would be the pros and cons of these roles?

The main difference is that while industrial researchers are increasingly publishing the outcome of their important – precompetitive – research, they do it as a 'sanity check', to verify they are moving in the right direction. In the academia, scoring papers might be for someone an objective by itself (for career reasons), but a 'real' researcher will more or less do the same thing. It is also likely that no single organization – including corporate behemoths like Google or

ACADEMIA SHOULD BE ABLE TO RELY ON SIGNIFICANT AND SUSTAINED BASIC RESEARCH FUNDING.

Apple – can outperform the whole research community. This implies that companies should 'buy' or 'consume' more research than they 'produce'.

When technology is transferred from academia to the industry, what are the biggest hurdles to overcome?

It is a well known fact that a research prototype requires an effort that respresents a small fraction (someone says 1%; I am not so pessimistic) of a 'beta' product/service prototype, and that in turn the passage from the 'beta' version to production requires a similar additional effort.
The availability of experienced and risk-taking investors is the main need. The intellectual property (IP) legislation (and the IP protection costs, including litigation and the efficiency of the legal system) is another important aspect for the right recipe.

From an academic point of view, how important it is for a new algorithm, design or technology to be viable and working under different conditions and at all times or is the focus mainly about new ideas rather than thinking about their deployment in industry?

A new idea in Robotics, Cognition, AI, aiming to be transferred to the 'real world', needs to be, first of all, replicable – especially because those disciplines have important scientific implications (for example, for biology and brain sciences) – and then be measurable (in terms of its capabilities to work properly in a varied set of environments while performing a diverse set of tasks).
A real research advancement will naturally lead to new applications. And in turn, we can not expect a long-term sustainable economical development without a continuous inflow of new basic research results.

From an industry point of view, would you say that the role of academia is to come up with new ideas, design and innovations while it is the industry's job to make these new technologies viable, profitable and working?

Yes. We live in an increasingly 'liquid' society where the borders are continually being blurred, so we should be flexible. Moreover, academia should be able to rely on significant and sustained basic research funding to make the process of technology transfer sustainable in the long run.

Can you think of a project that wouldn't have commercially succeed if there had been no collaborative efforts between academia and industry?

The biggest business successes of our times come from the industry take-up of breakthrough basic research ideas which are then translated into novel products and services through applicative research and business innovation.
We should work to reduce the lead times for the benefit of the economy and the society.

THE BIGGEST BUSINESS SUCCESSES OF OUR TIMES COME FROM THE INDUSTRY TAKE-UP OF BREAKTHROUGH BASIC RESEARCH IDEAS.

ALTHOUGH THE MOST COMMON USE OF ROBOTIC TECHNOLOGY IS ITS EMPLOYMENT IN PRODUCTION FACILITIES, ROBOTS ARE OF VITAL IMPORTANCE TO MANY OTHER, SMALLER INDUSTRIAL BRANCHES. SOME OF THE ROBOT USES WE TEND TO DISREGARD ARE THEIR INCLUSION IN THE ENTERTAINMENT INDUSTRY, SPECIFICALLY FILM INDUSTRY, AS WELL AS THEIR DEPLOYMENT IN DEMINING. HOW CAN ROBOTS HELP PEOPLE AND SAVE LIVES? ARE ROBOT PORTRAYALS IN MOVIES REAL ENOUGH FOR A ROBOTICIST TO SUSPEND HIS/HER DISBELIEF? WE HAVE ASKED TWO ROBOTICS EXPERTS, DR. RAJ MADHAVAN AND DUSTIN WEBB TO GIVE US THEIR INSIGHT ON THESE QUESTIONS.

HUMANITARIAN ROBOTICS AND AUTOMATION TECHNOLOGIES

IMPROVING THE QUALITY OF LIFE FOR HUMANITY

RAJ MADHAVAN

Robotics & Automation (R&A) technologies have the potential to transform and positively impact the lives of several people around the globe by addressing some of the most pressing and unsolved needs of humanity, thereby elevating their Quality of Life (QoL). I believe that most of the past and current research and development efforts in robotics and automation are squarely aimed at increasing the Standard of Living (SoL) in developed countries where housing, running water, transportation, schools, access to healthcare, to name a few, are taken for granted. Humanitarian R&A, within the context of this article, is taken to mean technologies that can make a fundamental difference in people's lives by alleviating their suffering in times of need such as during natural or man-made disasters or in pockets of the population where the most basic needs of humanity are not met, thus improving their QoL and not just SoL (My thoughts on SoL are also influenced by the seminal work of E.F. Schumacher particularly by his exposition of 'Buddhist Economics' [1]).

I am primarily interested in R&A efforts for improving the QoL for humanity, especially in the development of practical solutions that can be deployed in a truly useful, effective, and scalable fashion. Many of the underlying theoretical frameworks of existing R&A technologies are at a sufficient level of maturity and are widely accepted by the academic community after having undergone the scientific rigor and peer reviews that accompany such works. Yet, several of these frameworks, when subjected to the demands of deployment in practical situations, reveal their brittleness and lack of robustness (e.g. Deepwater Horizon oil spill in the Gulf of Mexico and the Fukushima Daiichi nuclear disaster). My current work focuses on the applied use of robotics and automation technologies for the benefit of under-served and under-developed communities by working closely with them to develop solutions that showcase the effectiveness of R&A solutions in domains that strike a chord with the beneficiaries, thereby also ensuring sustainability of such developed solutions.

Unmanned Aerial Vehicles (UAVs), popularly referred to as drones, have received unprecedented attention in the last few years. From Amazon's ambitious plan of its fleet of prime air package deliveries right to our doorsteps to USAF Reapers firing hellfire missiles at targets in Afghanistan and Iraq to paparazzi chasing celebrities to get that prized picture of a Hollywood star's baby, they have conjured up images only limited by our vivid imaginations. Based on a recent study, it is expected that the market value of drones for the civilian sector will be a billion dollar industry by

2020! Whatever mode of control they are flown under (autonomous or remotely piloted by ground operators), for a destructive or a constructive mission, UAVs evoke negative connotations in the minds of the public that border on the absurd to highly valid concerns. While the US Department of Transportation's Federal Aviation Administration (FAA) is currently drafting and revising policies and procedures to regulate the use of UAVs [2], by and large, it has only fueled speculations and confusions. My take on UAVs is that they are an invaluable tool and an 'eye-in-the-sky' asset. In collaboration with researchers and governments, I am engaged in the development of solutions providing images of unsurpassed quality in civilian applications ranging from disaster relief, environmental monitoring, and surveillance, to combating animal poaching efforts. In GPS denied environments and areas where immediate access to satellite imagery and communication networks is not available (which happens to be the case during disasters and in developing countries), UAVs can provide the much-needed high-resolution and on-demand images for situational assessment and awareness that literally could mean the difference between life and death. As a roboticist who has mainly worked on ground robots, I am also interested in the use of Unmanned Ground Vehicles (UGVs) teaming with UAVs to complement the overall effectiveness and robustness of a mission in such scenarios.

Within the IEEE Robotics Automation Society, I lead the Special Interest Group on Humanitarian Technology (RAS-SIGHT) whose mission is the application of R&A technologies for promoting humanitarian causes in collaboration with global communities and organizations.

One of the signature activities of RAS-SIGHT has been the establishment of the Humanitarian Robotics and Technology Challenges (HRATCs). HRATCs are an unprecedented opportunity for the robotics and automation community from around the world to collaborate using their skills and education to benefit humanity. The problems (challenges) are framed with the environmental, cultural, structural, political, socioeconomic, and resource constraints such that the developed solutions can be effectively deployed and sustained.

The first HRATC edition kicked off in 2014 with a Challenge that focuses on promoting the development of new strategies for autonomous landmine detection using a mobile (ground) robot. The strategies developed by the participating teams are objectively and quantitatively evaluated according to the following criteria: exploration time and environmental coverage; detection and classification quality, i.e., when a metallic object is detected, it should be classified correctly as a landmine or non-landmine; landmine avoidance, i.e., while navigating, the robot should not go over landmines.
The Challenge takes place in three phases: 1) Simulation Phase, 2) Testing Phase, and 3) Challenge Phase. Teams are progressively eliminated after each phase and the remaining teams move on to the next phase culminating in the Challenge (Finals) phase. It should be noted that the teams do not need to purchase or build a robot instrumented with sensors or develop any of the accompanying software. Every team can participate remotely in each of the phases. The main goals are to:
- Develop an open source and free software for reliable and robust detection and classification of landmines and subsequent clearance,
- Inspire, Encourage, and Educate researchers and students on the benefits of deploying R&A technologies for the benefit of humanity, and
- Provide a platform for exchanging ideas on addressing pressing needs across the globe via R&A technologies.

In its second year, HRATC Finals are being held in conjunction with the Robot Challenges at the IEEE International Conference on Robotics and Automation (ICRA) in Seattle from May 26-28, 2015. 3 teams would be selected as the overall, second-place, and third-place finishers, respectively. More details on HRATC'14 are detailed in [3] and for additional information on HRATC'15, see http://www.isr.uc.pt/HRATC2015/. We see this Challenge as a multi-year effort at the end of which it is our hope that, with the help of the academic and industrial communities, a sustainable, cost-effective, and meaningful solution would become available to this problem that has plagued several worldwide communities for a long while. In successive iterations, we will continue to refine the development of new strategies for autonomous landmine detection.

It is my firm belief that developing sustainable R&A tools, methodologies, and hardware platforms with useful sensor suites, identifying gaps and initiating a dialog between different stakeholders will help in alleviating suffering for mankind by increasing the effectiveness and/or efficiency of humanitarian workers on the ground. As a desirable byproduct, it also will educate the public on the good and benevolent aspects, which in turn will facilitate societal acceptance of R&A technologies. With my collaborators and like-minded individuals, I am engaged in efforts to bring together researchers, practitioners, humanitarian relief workers, responders, analysts from

1. The views and opinions expressed in this article are those of the author and do not represent those of the organizations and institutions he is affiliated with.

the field and humanitarian aid agencies, and foundations from several countries to understand the current and future role R&A technologies play in alleviating suffering of humanity in times of need [4]. If you're involved in similar activities and/or interested in working together to make this world a better place, please drop me a note at rajmadhavan.tech4humanity@gmail.com.

Dr. Raj Madhavan is a research scientist with the Institute for Systems Research and a member of the Maryland Robotics Center at the University of Maryland, College Park (currently on leave). He has been serving as the Vice President of the Industrial Activities Board (2013-2016), Chair of the Standing Committee for Standards Activities (2011-2016), and since 2012 as the Chair of the Special Interest Group on Humanitarian Technology, all within the IEEE Robotics and Automation Society.

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I CAN'T BELIEVE IT!

DUSTIN J. WEBB

I remember sneaking upstairs and hiding behind our couch in an attempt to watch The Terminator when I was a child. I would have been around eight years old at the time and my mother was unquestionably against letting me see it. The only scene I remember was the one where the T-101 chassis walks out of the flaming wreck of a mangled diesel.

I remember thinking that was awesome. Even now I think it is a great scene. But it is one of those scenes that requires suspension of disbelief for me. What sensory input did this machine receive? And did it lose some of that input when the biological components were incinerated? It walks out of the fire seemingly unfazed, so are we to assume not? In which case we are left wondering "why not?!"

Every robot movie I can think of raises the specter of disbelief. It would be impossible to enjoy a robot movie if one could not suspend disbelief. Some movies require a greater amount than others of course. Take Chappie for instance. I found this movie simply too incredible. To the point that it was too frustrating to be enjoyable. Suffice it to say this movie takes the ideas of the singularity to the extreme. The producers of this movie could have benefited from consulting an expert on artificial intelligence.

When you think seriously about the robots that come out of Hollywood you realize they are often not that different from real life robots. In fact, I would be surprised if even the most well informed roboticists

could always differentiate between Hollywood's creations and those coming from academia or the garages of hobbyists. The robot sentries in Elysium are a good example here. They look as though they could be the next evolution of the Boston Dynamics Atlas robot. Of course, Elysium is new enough that this could be a case of art imitating life, or life imitating TV, as Ani Difranco might say.

I submit that the need to suspend disbelief for a roboticist generally comes from the differences between the capabilities of fictional robots and real ones. While there are not a lot, the differences that exist are important.

Consider the issue of power for example. Even movies that address it do so only tangentially. Bicentennial Man shows Andrew, the robotic protagonist, plug himself into a wall socket. This tells us nothing about Andrew's power requirements, how long he can go between charges, or how the power is stored. I speculate that this issue is avoided because the power requirements of robots are not generally well understood. And for those that do understand them, it can still be explained away by some means like accepting that that the inherent dangers of energy dense power supplies are outweighed by the benefits of the robot's utility as in The Terminator television series.

Other problems are more subtle. Differences in mechanical capabilities and available processing power often stand out to me here. Let us look at a difference in mechanical capabilities first. Fictional robots are frequently portrayed as having super human strength or speed. To have these abilities they must have actuators capable of producing incredible forces, and quickly if they are to be fast. This of course requires a great deal of energy, at least when using electromechanical motors. Assuming the Iron Man suit has a power source capable of supplying the necessary energy are we really to accept that its tiny actuators can stand up to the g-forces produced on its ailerons during high speed flight? It definitely sucks the fun out if it if we don't.

Now let us think about processing power. Fictional robots run the gamut of computational resources. From the tiny board giving rise to all that seems to be Wall-E through Data's highly computationally capable positronic brain to the vast computational resources of the starship Andromeda and its humanoid avatar. But what kind of computational resources are really necessary? It depends on the tasks a given robot is expected to perform and sometimes the complexity of the environment in which it is intended to operate. Wall-E was clearly knowledgeable and intuitive. Could such a small board have provided all the computation necessary? It also depends on the underlying algorithms driving the robot and the capabilities of the board. So, maybe?

That brings me to the most glaring difference between real and fictional robots. That is the disparity in the levels of intelligence. This is no surprise to anyone, roboticist or otherwise. The walking-talking automatons that we have grown accustomed to in movies do not yet exist in the real world. Real robots are dumb.

One might ask whether this is a robotics problem though. After all there is an entire field of researchers dedicated to studying artificial intelligence. But a lot of roboticists are motivated by trying to understand intelligence and use robotics as a vehicle for doing so. Similarly, a lot of AI researchers seek to bring to life the robots that are still relegated to science fiction. For many of us these fields are intrinsically linked.

The fact that we have not yet been successful in creating an AI with human-level, or even near human-level, intelligence has become something of a joke at this point. We were going to solve the vision problem over a summer. How far could motion planning, control, manipulation, and the like be behind that? As we know now these are all incredibly challenging problems.

Building a fully capable robot, a robot that can handle the complexity of the world we live in, compounds these problem because it seeks to solve all of them simultaneously. There is a lot of promising work on this front however. Just look at the DARPA Grand Challenge, the DARPA Urban Challenge, and the DARPA Robotics Challenge. And take a look at the advances in reinforcement learning and deep learning on challenging tasks like playing Atari and planning. Every day our technology is becoming more knowledgeable and capable of handling more complicated environments and more complicated problems.

We still have a long way to go before the likes of C-3PO will be walking around doing our bidding. But we will solve the hard problems and they will become parts of our everyday lives. In the meantime we will have to settle for suspending disbelief.

Dustin J. Webb is currently a Ph.D. student at the Department of Computing, University of Utah, working with Dr. Suresh Venkatasubramanian. His research is focused on developing algorithms to address the motion planning and control problems using deep learning.

IJARS HAS, SINCE ITS START OVER A DECADE AGO, WITNESSED NUMEROUS DEVELOPMENTS IN THE ROBOTICS FIELD. DR. YOSEPH BAR-COHEN HAS WRAPED-UP THE LAST 10 YEARS OF RESEARCH IN ONE OF ITS PARTICULAR SUBFIELDS - THAT OF HUMANOID ROBOTICS. YOU CAN READ HIS OVERVIEW BELOW.

THE PROGRESS IN HUMAN-LIKE ROBOTS TOWARDS HAVING THEM IN EVERY HOME AND BUSINESS

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INTRODUCTION

The human species has to date been the most sophisticated result of roughly four billion years of evolution, the result of nature continually exacting trial and error experiments. In both art and technology, humans have always been inspired to mimic and adapt human appearance, our capabilities and intelligence. Related biomimetics objectives consist of the effort to engineer robots that have the appearance, as well as the behaviours and functions that mimic biological humans [8, 10, 13, 46].

Advances in computer science, including powerful miniature microprocessors, materials science, real-time imaging and recognition, speech interpretation, biped dynamic control and many other technologies have led to the creation of life-like robots that closely resemble humans [6, 9, 10]. Such robots are being developed with impressive capabilities and sophistication, rendering them capable of verbally and facially expressing emotions, and responding emotionally in conversation with natural humans [11]. Electroactive polymers (EAP), also known as artificial muscles [7], are being used to produce biologically inspired mechanisms that were once considered only to exist in the realm of science-fiction. As progress is being made, having such robots present in our lives, whether at home or in business, is increasingly becoming a realistic achievement. This paper summarizes the state-of-the-art technology being used by the developers of human-like robots and the challenges they face in the process.

To be considered a human-like robot it is necessary to be similar to humans; thus, the robot needs to have a central torso with a head on top, two arms that are arranged symmetrically on either side, as well as two legs that are symmetrically arranged below the torso to provide upright bipedal posture and mobility. The arms must have hands on their ends and must be equipped with fingers for grasping and manipulating objects, while each leg has to have a foot, used for locomotion. Robots with human-like features are known by several names including humanoids, androids and automatons [9, 34]. The author distinguishes between the terms ‘humanoids’ and ‘human-like robots’ as follows:

HUMANOIDS – these robots have the general appearance of a human including head, torso, arms and possibly legs. However, these robots appear as machines, its head mostly shaped as a helmet. Making such robots is easier than creating human-like counterparts, since their fabrication does not involve the complexities of producing fully human-like features. An example of a humanoid is the recently developed NASA Johnson Space Center (JSC)’s Valkyrie robot (see Figure 1).

HUMAN-LIKE ROBOTS – these robots are designed and fabricated to appear as realistically human as possible and great efforts are made to copy the exact appearance of humans. The roboticists creating these robots consist primarily of scientists and engineers from Japan, Korea and China, as well as a small number in the USA. An example of a human-like robot is shown in Figure 2, where an impressive similarity can be seen between the Chinese roboticist Zou Renti and his clone robot.

Figure 1: The NASA Johnson Space Center's humanoid Valkyrie robot. Source: NASA-JSC/DARPA.

Figure 2: An example of a human-like robot showing the roboticist Zou Renti (China) and his clone robot. The photo was taken by the author at Wired magazine's NextFest, held on 14 September 2007 in Los Angeles, CA.

HISTORICAL REVIEW

The development of human-like robots has been an evolutionary one and an artistic view of this evolution is shown in Figure 3 [9]. A definition of the word 'robot' can be given as follows: a machine with human appearance that performs complex tasks including walking and talking. The word 'robot' was used for first time in the play Rossum's Universal Robots (R.U.R.) by Czech writer Karel Čapek in 1921 [12] and was derived from the Czech word robota, meaning compulsory labour, hard work or slavery. Over the years, the word has evolved to increasingly become associated with intelligent mechanisms having biologically inspired shapes and functions that are particularly human-like.

The ancient Greeks were the first to envision machines that looked human. One of their gods, the metal smith Hephaestus, was philosophized to have created his own mechanical helpers in the form of young women who were strong, vocal and intelligent [37]. In the 16th century, a Jewish legend told of a servant called the Golem of Prague, who was brought to life by a rabbi called Loeb. Another famous story about creating a human-like form is the novel Frankenstein [41], in which a monster is created of human body parts and brought to life by the scientist Victor Frankenstein. The common thread to the golem and Frankenstein stories is that both describe the instilling of life into a human-like form, acts that ultimately ended in disastrous consequences. In general, Western culture suggests that human-like creation has the potential for evil if it is given the freedom to act without control.

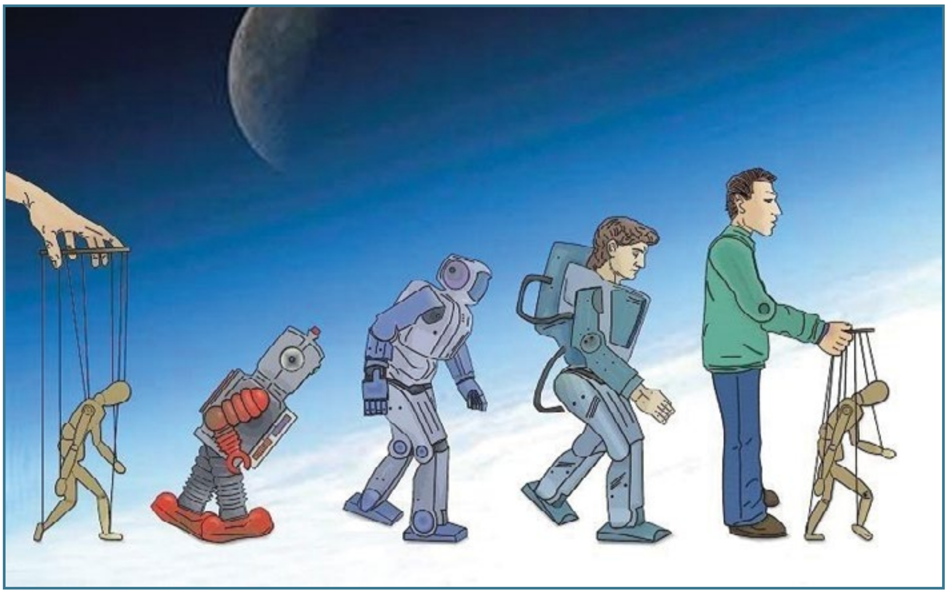

Figure 3 Artistic vision of the evolution of human-like robots (illustration courtesy of graphic artist Adi Marom) [9].

Leonardo da Vinci is attributed as the first individual who made a sketch of a human-like machine. In 1495, da Vinci designed a mechanical knight, known as Leonardo's robot [38]. The design Leonardo developed emulated human movement. Rosheim extensively studied Leonardo's drawings and using computer simulations, determined that the machine had been able to sit, wave its arms, bend its legs, move its head and open and close its jaw (http://itotd.com/articles/547/leonardos-robots/).

French engineer and inventor Jacques de Vaucanson is credited for being the first to produce a machine that appears and acts human. The human-like machine he created in 1737 is called "The Flute Player". His work was followed by an era of many artists who produced machines with capabilities that emulated human appearance and movement. Another famous example of such a machine produced in de Vaucanson's era is "The Writer", created by Swiss clockmaker Jacquet-Droz, who completed it in 1772. Jacquet-Droz's machine was made to act like a young boy writing at his desk and is able to write custom text at a length of up to 40 letters. During this time, developers used actuated mechanisms that were limited in terms of capability, driven by mechanical energy stored in a spring.

Equipping a human-like robot with the capability to operate intelligently is one of the most important aspects of creating a smart, life-like machine. In nature, the need for high intelligence is dictated by the critical need to survive and involves dealing with the surrounding environment and its risks and hazards. In contrast, rapid advances in making life-like robots is motivated by efforts to make some aspects of robots better than humans; this is achieved by the development of effective microprocessors, autonomous operation algorithms, human-like materials, dynamic stability and biped mobility, as well as sensors that imitate our senses (seeing, hearing, smelling, etc.). An example of the use of life-like material in a human-like robotic head is shown in Figure 4, where human skin is imitated using Frubber skin, developed by David Hanson [9].

Figure 4: Instilling intelligence into a human-like robot requires sophisticated software algorithms. The head (created by David Hanson) and the hand (created by Graham Whitely) shown in this photo are located in the author's NDEAA lab at JPL.

Making "smart robots" became possible once powerful processors had been developed. The era of digital computers began in 1946 with the development of the first large-scale, general-purpose, electronic digital computer called the ENIAC [31]. In 1950, the possibility of building thinking and learning machines was raised for the first time [45]. As a result of advances in making increasingly powerful microprocessors with high computation speeds, large memory capacities, wide communication bandwidth and highly effective software tools, intelligent robots are becoming significantly more sophisticated and exhibiting greater human-like capabilities [1, 10, 14, 27, 32].

Operating a robot in natural environments that contain complex and unpredictable obstacles involves many challenges; it is virtually impossible to explicitly pre-program a robot for every unforeseeable circumstance. Therefore, the robot needs to be able to deal with the terrain on its own and autonomously address the challenges that it encounters, as well as learn from its experience and adapt accordingly. For this purpose, researchers in the field of artificial intelligence (AI) are using concepts and methodologies inspired and guided by nature [2, 6, 9, 18, 19, 21]. The software used in robots increasingly resembles the organization and functionality of the human central nervous system, thus helping robots to perceive, interpret, respond and adapt to their environment.

To make robots appear more expressive, believable and heart-warming, roboticists are increasingly collaborating with artists in developing human-like robots. Additionally, robotic technologies are increasingly entering our lives through entertainment, education, healthcare, domestic assistance and military applications. Entertainment applications are the most widespread and include human-like robotic toys that are available for purchase in many stores. One indicator for the direction of robotic toy development is the human-like robot toy called Zeno. It has been developed as an interactive learning companion and seeks to become a synthetic friend dedicated to the child for whom it has been purchased (Figure 5).

Figure 5: Zeno, held here by Yardena Bar-Cohen, is a human-like robot toy that is being developed as an interactive learning companion at Hanson Robotics.

In general, robots are widely being used in industry to perform complex manufacturing tasks including the assembly of automobiles. Other applications include planetary and deep ocean exploration; operating in areas with toxic gases, radioactivity, dangerous chemicals, bad odours, biological hazards, or extreme temperature environments; cleaning hazardous waste; sweeping mine fields; bomb disposal; search and rescue. In certain applications, a human-like form may not be the most effective for a specific task using current technology; for example, space exploration roboticists at Jet Propulsion Laboratory (JPL)/Caltech are developing an ape-like robot called RoboSimian (Figure 6). A futuristic vision of the role of human-like robots as human assistants in the planetary exploration of the universe is shown in Figure 7 , where the robot is shown as a cooperative helper.

Figure 6: The JPL's 4-legged RoboSimian (source: NASA/JPL-Caltech).

Figure 7: A futuristic vision of the role of human-like robots as human assistants in planetary exploration of the universe (illustration courtesy of graphic artist Adi Marom) [9].

THE NEED FOR ROBOTS IN A HUMAN-LIKE FORM

One may wonder why it is necessary to make robots look human. The answer partially lies in the fact that the world we built around us has been made to fit our average body size, shape and capabilities [25]. This includes our home, workplace, the tools we use, the car we drive and the height at which we keep our possessions. Therefore, in order to provide the most effective assistance, the robot should be made to match our shape, size and capabilities. A human-like configuration will allow the robot to reach a door handle, listen to us at eye level, climb stairs, sit on our chair, drive our car and perform many other support tasks for us. Additionally, it is highly desirable for the robot to be able to speak our language in order to make communication simpler. Since we respond intuitively to body language and gestures, it is essential that the robot executes facial and body expressions. Furthermore, it is also argued that a human-like form is the most efficient for having humans teach robots (for example, motion capture or using a demonstration that the robot then imitates), which may play a fundamental role in making robots more intelligent [43]. It is interesting to note that children today are spending more time with smart phones, tablets and computers than with peers of their own age or with others. They are growing up with less developed social skills and a poor understanding of the body language cues that were taken for granted by prior human generations. This increasingly growing concern can be addressed by incorporating human-like robots into education, therapy, or games while providing realistic simulation. Robots are already being used for treating children with autism and the reported results show great promise [16].

Constructing a robot that looks and behaves like a human is only one level of the complexity of the challenges related to this area. Making it function within and outside our homes requires autonomous operation of dealing with static objects, such as stairs and furniture, as well as negotiating with dynamic elements such as people, pets and automobiles. The robot may need to be able to walk in a crowded street, cross a street with busy traffic while obeying pedestrian laws, or walk in a complex terrain consisting of unpaved roads and various obstacles. The required dynamic control capability for determining the available path within the robot's capability is currently under development in many labs worldwide [42].

MAKING A HUMAN-LIKE ROBOT

Several key technologies are essential for constructing a life-like robot with a human-like form including the materials, actuators, sensors, smart controls, mechanisms of mobility and manipulation of the hands and legs, hearing and verbal communication, seeing and image interpretation, the ability to identify and avoid obstacles, as well as determining and addressing risks. The human-like robot needs to have effective control and artificial intelligence algorithms for allowing it to operate in human-like form and to interact with its environment and with humans [35]. It needs to have parts and functions that are as similar as possible to those of a real human; these primary features are illustrated in Figure 8.

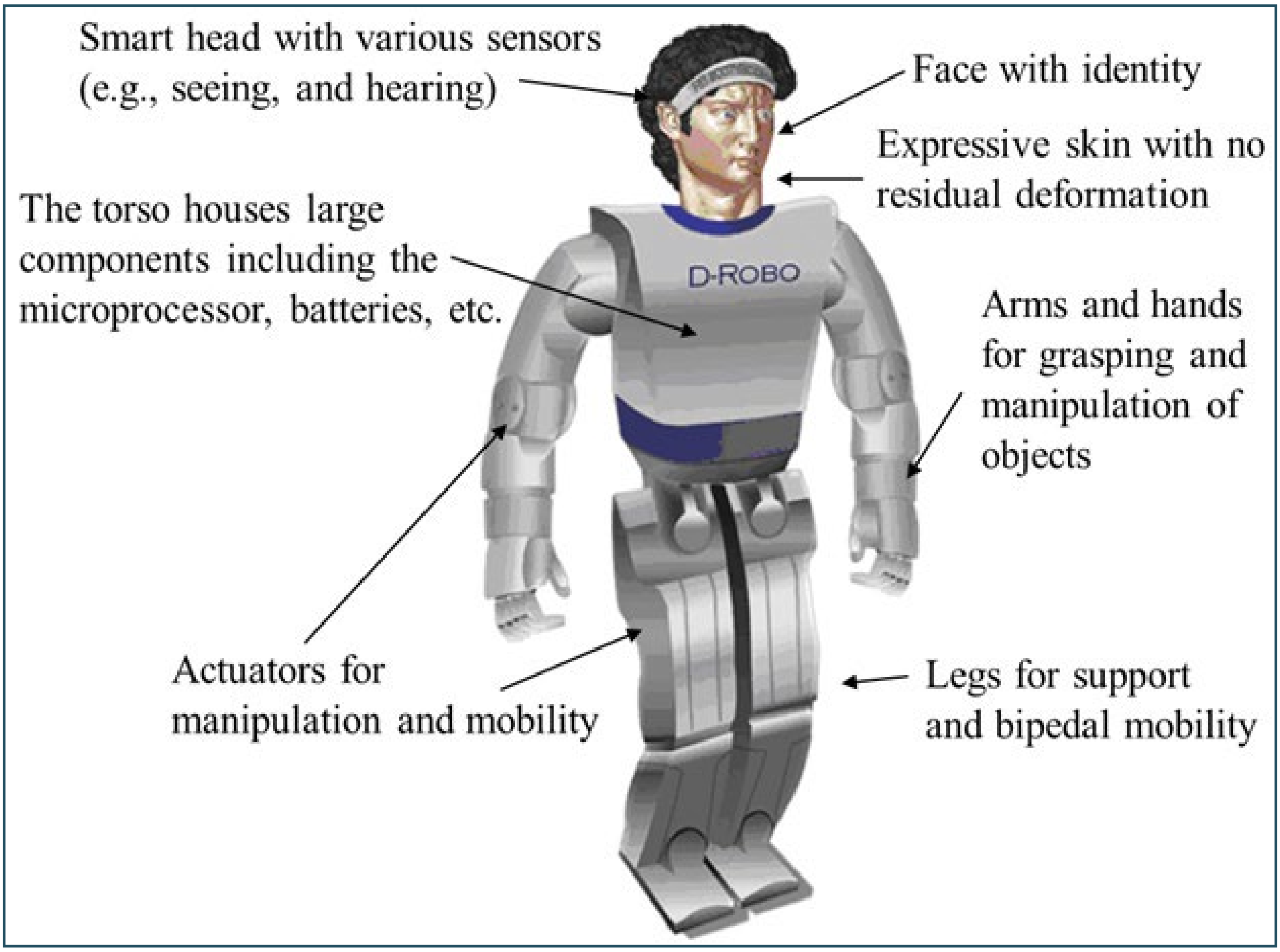

Figure 8: The components and functions of a human-like robot (illustration courtesy of graphic artist Adi Marom) [9].

Head: the head consists of sensors that sense the environment and help the robot to operate safely in its interaction with humans and the surrounding terrain. Miniature video cameras provide vision capability as well as communication cues from facial expressions to help the robot act socially appropriate. Microphones measure sound and provide speech content, as well as information about the type and the direction of the sources. Speech recognition supports verbal communication and the sophistication of these technologies is currently able of "understanding" hundreds of words [9]. To communicate with humans, the robot uses a voice that is synchronized with lip movements and body gestures. The head can also include an artificial nose and tongue to provide the robot with information about the smell of odours and the taste of objects.

Brain: the robot microprocessor is used as an equivalent to the human brain. It controls the operation and functions of the robot, including its mobility, image processing, verbal communication, body language and facial expressions, as well as many other tasks that the robot needs to perform. The significantly increased capability of microprocessors is implemented to improve the performance of these robots.

The field of artificial intelligence (AI) is enabling the creation of “smart” robots. AI is a branch of computer science that studies the computational requirements for tasks such as perception, reasoning and learning in order to allow for the development of the systems that perform these capabilities [39]. The objectives of this field are to advance the understanding of human cognition [26], understand the requirements for intelligence in general and to develop artefacts such as intelligent devices, autonomous agents and systems that cooperate with humans to enhance their abilities. AI researchers are using models inspired by the computational capability of the brain and explaining them in terms of higher-level psychological constructs such as plans and goals. Progress in the field of AI has enabled better scientific understanding of the mechanisms underlying thought and intelligent behaviour, and their embodiment in robots. The field of AI is providing important tools for human-like robots including knowledge capture, representation and reasoning, reasoning under uncertainty, planning, vision, face and feature tracking, language processing, mapping and navigation, natural language processing and machine learning. AI-based algorithms are used where case-based and fuzzy reasoning allows for automatic and autonomous operation [6, 9, 29]. Even though AI has led to enormous successes in creating smart computer-controlled systems, its capability is still far from reaching the level of human intelligence.

Face: the face provides the identity and allows for making facial expressions as a nonverbal means of conveying social information. Robots are already beginning to make realistic facial expressions, rendering them significantly more life-like [9, 22, 23]. Humans are visual creatures and our ability to recognize faces and facial expressions is hardcoded within the human nervous system. For this reason, mimicking the human face’s appearance, shape and movements is essential for creating life-like expressions.

Skin: to appear human-like, the robot needs to be covered with an artificial skin that looks and feels (e.g., temperature) like a living person. This requires the skin to be highly elastic, as well as enabling facial expressions without residual deformation. One of the notable developed artificial skins is Frubber, developed and reported on by Hanson [22]. An example of a robotic head that was made with this material is shown in Figure 1. The rubbery material Hanson used to emulate the skin requires minimal force and power in order to produce naturally looking large deformations. The robot head that is shown in Figure 9 serves as a platform for engineers worldwide who are developing artificial muscles and need to test their developed actuator [7].

Figure 9: Using Frubber, a human-like head that makes facial expressions was produced as a platform for testing artificial muscles. The head created by David Hanson of Hanson Robotics and photographed by the author at JPL. This head is located at the author’s NDEAA lab, Jet Propulsion Laboratory (JPL)/Caltech, Pasadena, CA, USA.

Arms, hands and legs: the arms, hands and legs of human-like robots have the same basic functions as they do for humans. While these might seem easy functions to perform, they are difficult to control in robots. Advances in technology in dynamic balance control and bipedal operation have made stable walking an established capability of humanoid and human-like robots [36]. To mimic natural human movement, sensors are mounted on the legs, arms and hands, including pressure sensors that determine grip pressure, as well as touch sensors to interpret tactile impressions. Sensors are also used to trigger responses if the robot is exposed to unsafe conditions. The success in making human-like hands, arms and legs for robots has benefited disabled humans, since highly effective and life-like prosthetics are increasingly being developed (Figure 1). Another area of development that benefits from bipedal mobility is walking chairs as a replacement for wheelchairs, enabling users to operate in areas that are not flat. An example of a walking chair was demonstrated at the 2007 NextFest Exhibition of Wired magazine, which carried a person while climbing stairs (see).

Actuators and artificial muscles: actuators emulate muscles and are used to mobilize robots, as well as move appendages and other parts. The types of actuators that are generally used include electric, pneumatic, hydraulic, piezoelectric, shape-memory alloys and ultrasonic actuators. Electric motors are widely used to produce the movements of human-like robots, but they behave differently than our natural muscles and have an entirely different operational mechanism. Natural muscles are both compliant and linear in behaviour [17]. Emulating the operation of muscles is important, since they address key control requirements for the life-like operation of robots.

Figure 10: A prosthetic arm developed under the DARPA programme. Photographed by the author at the DARPATech 2007, held in Anaheim, CA, 7-9 August, 2007.

The actuators that come closest to emulating natural muscles are electroactive polymers (EAP) and for this reason are referred to as "artificial muscles" [7]. Many of the EAP materials that are known today emerged in the 1990s but remain weak in terms of their ability to perform significant mechanical tasks such as lifting heavy objects. Recognizing the need for international cooperation, the author initiated and organized in March 1999 the first annual international EAP Actuators and Devices (EAPAD) Conference [5]. At the opening of the first conference, he posed the challenge to scientists and engineers worldwide to develop a robotic arm that is actuated by artificial muscles to be able to win in an armwrestling match against a human opponent (see the icon of the match in Figure 12). In the first contest, an arm wrestling match with a human (a 17-year old high school female student) was held on 7 March 2005. Three robotic arms participated in the contest and the girl won against all of them. The second Artificial Muscles Arm-wrestling Contest was held on 27 February 2006. Rather than wrestling with a human opponent, a custom-made measuring fixture was used to test the EAP-actuated arms for speed and pulling force. To establish a baseline for performance comparison, the capability of the student from the 2005 contest was measured first. It is interesting to note that the 2006 results showed the capability (force and speed) of the EAP actuators to be two orders of magnitude lower than that of the student.

The current issue is that the available EAP actuators are still significantly weaker in force and operation speed compared to humans. Once sufficient advances have been made in EAP capability, a professional wrestler will be invited for a human/machine wrestling match.

Figure 11: The walking chair, called the Human-Carrying Biped Walking Robot (developed at Waseda University, Japan) is demonstrated carrying a human and walking. Photographed by the author at the NextFest Exhibition 2007 held by Wired magazine.

Figure 12: The icon of the arm-wrestling challenge for artificial muscles matched against a human opponent.

THE CURRENT CAPABILITIES OF HUMAN-LIKE ROBOTS

Human-like robots today have impressive capabilities in terms of emulating life-like human performance. Snapshots are shown in Figure 13, presenting various actions of the humanoid robot Chroino, demonstrating the life-like movement capabilities that can be performed by this small human-like robot. Additionally, the humanoid robot HOAP [44] shown in Figure 14 performs a lifting task [video at: http://videolectures.net/aaai07_stoica_haop/]. Though these performances are impressive, current human-like robots are still unable to match the capability of humans as portrayed in science-fiction books and films. Nonetheless, though the portrayal of superior capabilities is still far from our current reality, works of science-fiction inspire and guide innovation in the development of these technologies, as well as alert us of the potential dangers and negative possibilities they may hold [28, 40]. These possibilities include acting as an imposer and performing criminal acts. Some of the most recent human-like robotic capabilities include robotic self-improvement following their production, since robots can self-learn and obtain periodic updates. The sophistication of these robots that are being developed includes fully autonomous operation and self-diagnostics. In the future, they may be designed to travel on their own to a selected maintenance facility and receive periodic check-ups and repairs. In case of damage, future robots might be constructed from biomimetic materials that are capable of self-healing.

Progress in voice synthesis, detection and recognition continues to improve interaction between human-like robots and humans [6, 9, 11, 24]. This technology is enabling robots to be sociable, to communicate verbally and expressing emotions while making eye contact and producing facial expressions, as well as responding to emotional and verbal cues [11]. These capabilities are advancing the emotional adaptation of human-like robots, since they interact and

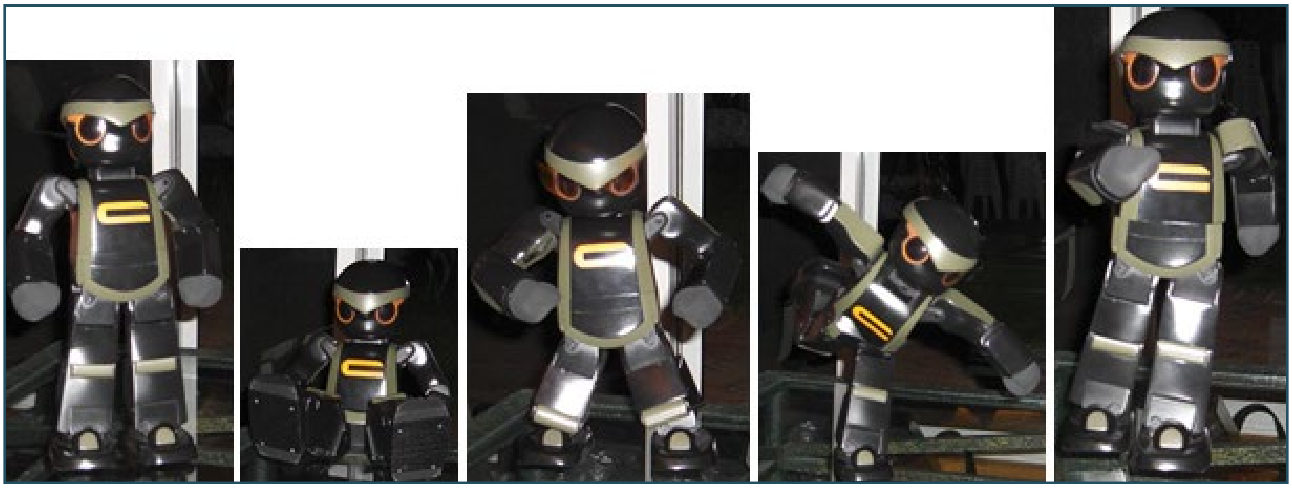

Figure 13: A series of snapshots showing Chroino (created by Tomotaka Takahashi, Robo-Garage, Kyoto, Japan). Presented at the Wired magazine 2007 NextFest held in Los Angeles, CA, on 14 September 2007 (photos taken by the author).

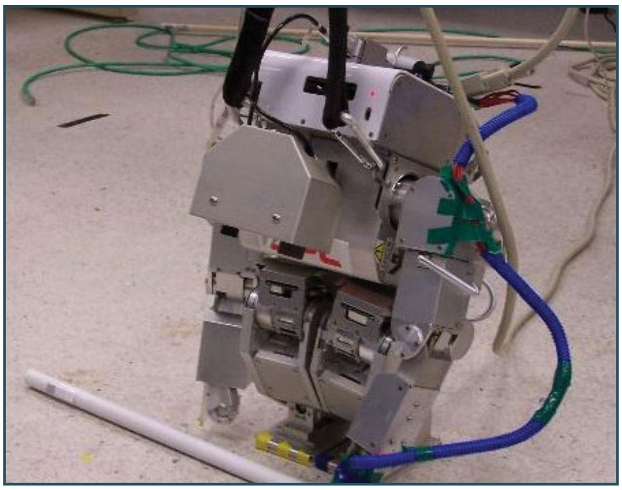

Figure 14: Robot picking up bars and preparing for frame assembly (images courtesy of Adrian Stoica, JPL-Caltech/NASA) [44].

communicate with people in ways that are intuitive to natural humans without the need for training. Robots are capable of mimicking humans by nodding when listening to someone that speaks to them, periodically blinking and looking the speaker in the eye for brief sessions. The conversations that can currently take place with robots are limited in vocabulary and content, but a significant amount of research is being dedicated to the biomimetic development of machine capability for understanding human conversation. The ability to converse is currently limited to a vocabulary of about 1000 words and the content of the conversations is limited. The ability to converse in a life-like form is only one of the important steps in making human-like robots appear believably like real humans. Furthermore, maintaining the movement of the robot in order to appear awake and alive consumes battery power and therefore limits its operation time, even when the most effective batteries are used.

Within the currently limited intelligent capabilities of human-like robots, there are various practical applications in which they can be used. The least complex approach is to control them in a telepresence form, where they are made to perform highly sophisticated functions that are human-controlled in an avatar form. An example of such a form of control and operation is the Robonaut I (robotic astronaut) developed in the 1990s at NASA Johnson Space Center (JSC), Houston, Texas, USA. This robot mirrors the physical movements of the upper section of the human body; a photo of the Robonaut performing a task is shown in Figure 15 . In recent years, the control was shifted from telepresence to fully autonomous operation. The original objective for its development was to operate as a cooperative robot that would perform functions outside the space shuttle or space station. Later, its applications were expanded to potential military and industrial tasks.

The enhanced capabilities of human-like robots offer great promise to the medical field and patient care applications. It is interesting to note that robotic surgery is increasingly becoming a critical part of the surgical tools that are used today and the results are encouraging further increase in their usage. Robots with a human appearance are being developed to assist in the recovery of patients, the elderly and others who need physical or emotional support. Humanoids are currently being used to remind patients to take their medication; the robots can act as an entertainment tool and they also monitor patient conditions and in case of signs of emergency, send videos and an alarm to staff at a central control room.

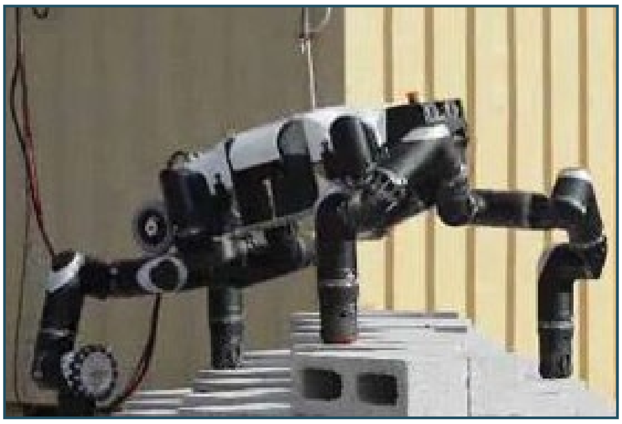

Figure 15: The Robonaut I is remotely controlled to perform physical tasks by mirroring the actions of a human (image: NASA Johnson Space Center).

Even though the progress in developing human-like robots is rapidly advancing, there are still many issues that limit their widespread use including their limited functions, relatively short battery charge and high cost. However, once human-like robots reach levels of mass production they are expected to become affordable and common household helpers that perform human-related services.

POTENTIAL IMPLICATIONS OF HUMAN-LIKE ROBOTICS

With the increase in our ability to make human-like robots that are life-like, there is a growing likelihood that they will be used to perform improper tasks and it is the author's opinion that they will inevitably be used for military applications. Beside the danger of using such robots against humans, there are ethical and philosophical issues and challenges that arise, and efforts are being made to address these before troublesome issues begin to materialize. The well-known science fiction writer, Isaac Asimov [3, 4] envisioned such possibilities and as a result devised his famous three laws of robotics, to which he later added his Zero Law. In Asimov's proposed laws, he suggested guidance for human and robot relations, where robots will act as servants and should not be allowed to cause harm or injury to humans. His laws are:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Asimov's Zero Law is: a robot must not merely act in the interests of individual humans, but of all humanity.

Advances in the capability and applicability of human-like robots are expected to lead to their entry into the industrial and household product market. However, contrary to other technologies, human-like machines may give rise to fears and aversion [9]. This possibility led the Japanese roboticist Masahiro Mori [33] to hypothesize that initially, there will be enthusiasm as the degree of similarity between robots and humans increases. However, when this similarity becomes extremely close, it will give rise to the strong rejection and dislike of these robots. The trend will reverse to a positive again once a great degree of similarity is reached. This attitude toward human-like robots with increasing similarity to humans is plotted graphically and includes a "valley" to reflect the dislike when the similarity is not fully close (Figure 16). There are many critics of this hypothesis, also known as the uncanny valley hypothesis, who suggest that it has never been proven in a credible experiment.

Besides the attitude towards human-like robots with a high degree of similarity to humans, there are also concerns about ethical issues that may need to be dealt with. Some of these concerns include the danger that robots might deliberately or accidentally harm humans, as well as being used in unlawful activities.

THE DARPA CHALLENGE AS INDICATOR OF THE STATE-OF-THE-ART

In an effort to accelerate the development of humanoid robots, DARPA has initiated a challenge intended to lead to advances in humanitarian and disaster relief, as well as related operations. The DARPA Robotics Challenge (DRC) consists of requirements for extending aid to victims of natural or man-made disasters and conducting evacuation operations. Due to grave risks to the health and wellbeing of rescue and aid workers, some disasters have been found to be too large in scale or scope for delivering timely and effective human response. By setting up this challenge, DARPA seeks to address the capability gap by promoting innovation in robotics for disaster-response operations, where robots will be made capable of executing complex tasks in dangerous environments. The focus of the challenge is on the ability of robots to use tools and equipment that are commonly available in human environments. Advances are sought in terms of having robots operate autonomously with perception and decision-making abilities, dexterity, strength and endurance. Addressing these challenges require the development of hardware and software, with a secondary goal of making this development accessible to a broad number of users in order to help lowering the cost of robotic systems, while at the same time increasing their capabilities. The availability of robotic hardware platforms with arms, legs, torso and head will allow teams without hardware expertise or the necessary hardware to participate.

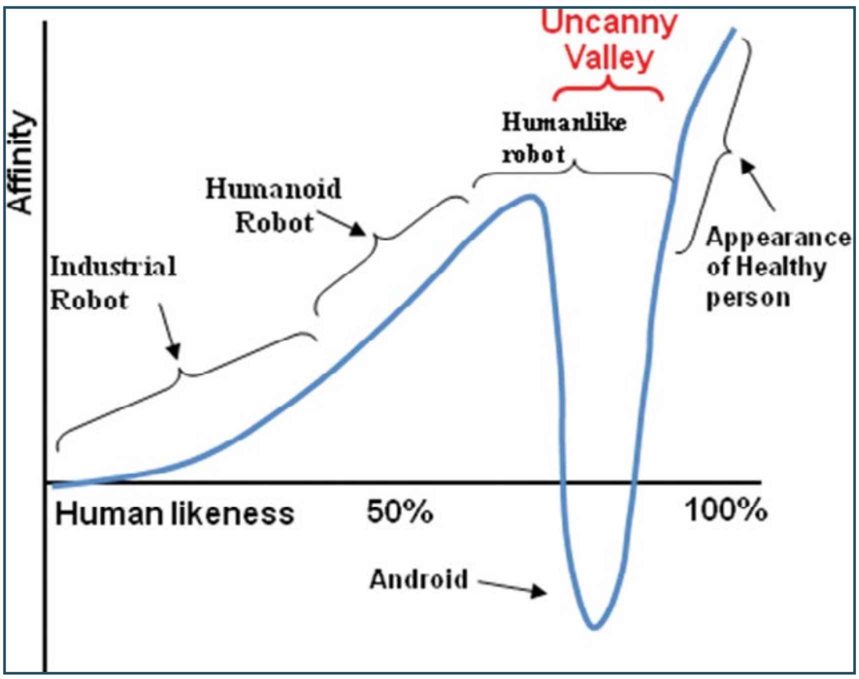

Figure 16: A simplified graphic illustration of the uncanny valley hypothesis.

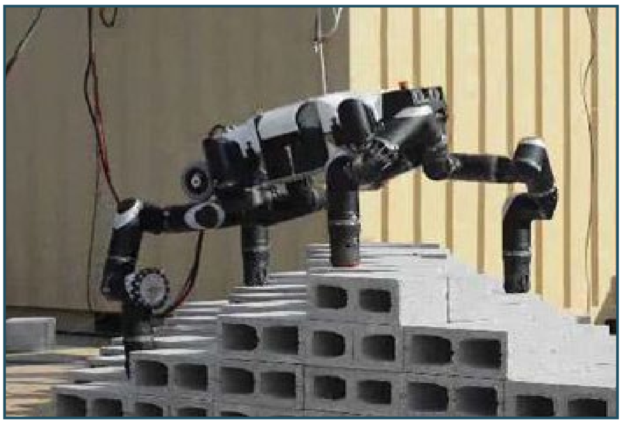

Figure 17: The JPL RoboSimian robot climbing rough terrain during the DARPA competition in December 2013 (image: NASA/JPL-Caltech).

During 20-21 December 2013, a contest including 16 competing organizations was held and the tests involved included eight tasks as follows:

1. Drive and exit utility vehicle
2. Walk across rough terrain
3. Remove debris from doorway
4. Open series of doors
5. Climb an industrial ladder
6. Cut though wall
7. Carry and connect fire hose
8. Locate and close leaking valves

The robot that achieved the highest score was one created by SCHAFT Inc. and was followed in second place by the Atlas robot (created by Boston Dynamics), which was programmed by IHMC Robotics (Florida Institute for Human & Machine Cognition). It is interesting to note that five of the top eight winning teams used the Atlas robot as their robotic platform for the development of their software. Carnegie Mellon University and the National Robotics Engineering Center's robot achieved third place in the competition, while an MIT team using the Atlas robot reached the fourth pace. Further, the Jet Propulsion Laboratory's robot RoboSimian reached fifth place. The JPL's four-legged robot (Figure 17) looked more ape-like than human and is being developed for potential use in future NASA in situ exploration missions.

The DARPA challenge will continue to be addressed in future competitions, with the next round expected to be held in June 2015 [http://www.theroboticschallenge.org/].

CAN ROBOTS EVOLVE TO BECOME FULLY HUMAN-LIKE?

Human-like robots are still far from replicating the full capabilities of real people. Current robots can perform only a limited number of functions and primarily execute specific tasks. Additionally, they are constrained when performing simultaneous tasks, i.e., walking is not performed while other physical tasks are being executed. Using AI, human-like robots are capable of interpreting facial expressions and have personalized behaviour that, rather than being made as exact copies, varies between the duplicates of particular robots. Some robots can walk or dance similarly to humans; however, there are many basic human tasks that remain beyond current robots' capabilities. These include conducting a comprehensive conversation with a human on a broad range of subjects, walking fast in a crowd without bumping into anyone and operating for extended periods of time without requiring a recharge. The process of overcoming these challenges related to the capabilities of human-like robots is expected to be evolutionary.

Lowering the cost of producing human-like robots requires the availability of standard hardware components and software platforms that are interchangeable and compatible. Furthermore, it will be helpful if more robotic platforms are written as open source software. Such platforms will allow scientists and engineers to avoid the need for having broad expertise and help them to focus on making improvements in their area of specialization. In addition, hardware and software will need to provide human-like robots with higher response speeds to changes in their environment. Robotic hardware will need to be made significantly lower in weight and equipped with many miniature lightweight actuators and sensors with distributed processing capability. Specifically, effective actuators are required with high power density, as well as high operational and reaction speeds. Furthermore, there is a need for advances in automated design and prototyping including 3D-printing that will allow for making miniature motors to control nuanced facial expressions or the movement of fingers, in addition to miniature drive electronics and highly sensitive sensors.

Making a robot that is human-like is a multidisciplinary task requiring expertise in such fields as electromechanical engineering, computational and material sciences, neuroscience and biomechanics. Advances in artificial intelligence, effective actuators, artificial vision, speech synthesizers and recognition, mobility, control and many other fields are significantly contributing to making robots act more human. The ability of future robots to conduct a comprehensive conversation will require the capability to recognize and "understand" more words than they can today, with significantly higher accuracy of interpreting text and verbal communication.

Making a human-like robot self-aware of the consequences of its actions and having it operate within the rules of what is "right" and "wrong" will ascribe to it a much more human-like character and make it safer to use. However, some claim that this is impossible. The problem here resides in the need to have the robot adjust its behaviour to take into account subjective uncertainties, with a sense of proportionality that is beyond the literal interpretation of situations. One possible way to address this challenge is to design robots that perform limited tasks only; however, this is unlikely to happen, as it would mean limiting technological development. Alternatively, robots might be operated under constant supervision, but this will defy the advantage of their acting as autonomous machines. One of the ethical concerns that are anticipated to result if robots are developed to operate without master-slave relationships is the possibility that the robot will be disobedient and exhibit unacceptable behaviour.

Increasingly, robotic systems such as drones are being used for military applications; it is inevitable that human-like robots will be used in this capacity, too. Robot armies may initially be operated remotely before becoming entirely autonomous. Contrary to real humans, robots do not suffer from deficiencies such as post-war syndrome or fear-induced emotions. Their availability may lead to their increased use in extremely risky military operations. Furthermore, if they are developed with artificial cognition and surpass human levels of intelligence, they may potentially turn against their human creators or human society as a whole.

As opposed to genetic cloning, which requires growth according to biological timescales and does not lead to an instant and exact duplicate of a human, human-like robots can be produced at the speed of manufacturing processes. As the rapid prototyping fabrication of human-like figures or models made by computer graphics become easy to produce by a 3D printer, our neighbourhoods may one day be filled with such robots. These may have the benefit of significantly helping humans, but will also potentially pose a significant risk to humans as a species.

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