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Robotics:

The flourishing landscape of robot standardization

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Technical standards are formal documents that establish uniform engineering or technical criteria, methods, processes and practices developed through an accredited consensus process. The purpose of this publication is to help raise awareness of standards, show the importance of standards, present real-world applications of standards, and demonstrate the role you can play in the standards development process. Knowledge of standards and standards activities can help facilitate your professional engineering practice and improve technological developments to meet the needs and improve the lives of future generations.

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Letter from the Editor

Robots Are Coming!

Robots are coming, robots are coming! Of course, that's no news. Robots in one form or another are everywhere around us. Their presence is growing rapidly in our everyday life and they are making our lives more productive. They have come a long way from automated assembly lines in the factories and cleaning homes to performing complicated lifesaving surgeries in hospitals and unmanned aerial vehicles (UAVs) in warfare. Continued evolution of the robots, and their applications in new domains, is in part due to the integration of sensors that enable the robots to understand physical quantities such as temperature, pressure, humidity and altitude, as well as the ability to process sight and sound (vision/image/video and audio processing). Furthermore, integration of networking and communication technologies, combined with advances in artificial intelligence and machine learning algorithms continue to put robotics on an accelerated path of innovations that will impact our daily lives tremendously.

So, as intelligent and networked robots become ubiquitous around us, it is imperative that there are standards set for design, deployment, maintenance, safety as well as interoperability among robots in a larger ecosystem built around such robots. A team of standards professionals have collected a detailed status of ISO standards projects in the article "The flourishing landscape of robot standardization". In the six working groups, these standards cover the topics of safety-related standards across different use domains:

- Vocabulary and characteristics
- Personal care robot safety
- Industrial safety
- Service robots
- Medical robot safety
- Modularity for service robots

Taking the topic one step further, Prof. Christian Wietfeld explains the need for standards in rescue robots at different layers of the entire rescue system. His article "Networked Rescue Robotics: Standards pave the way from successful prototypes to sustainable deployments" walks you through these layers and explains the need for standardizing various data formats. Imagine the kind of chaos that may exist if the rescue robots from different manufacturers, or even same manufacturer but different generation/version, could not communicate effectively with each other. This reminds me of the "1904 Baltimore Fire" chaos when firehoses were found to be incompatible with Baltimore's fire hydrants, rendering several hundred fire trucks from other cities useless while the city burned. One would hope that the rescue robots will provide a solution to ease the chaotic situation caused by whatever the nature of emergency (fire, earthquake, flood, etc.). That's why we need standards!

Dr. Koji Kamei takes us deeper on the tour of standards as used in the cloud for robotics. His article "Standardization Activities for Robotic Services" is a perfect complement to the Rescue Robotics.

Still interested in more information about Robotics and Standards? Checkout the comprehensive collection of information put together by IEEE's own Robert Craig as the newest member of the Standards Education team. Welcome aboard, Robert!

As academia and industry continue to advance the field of robotics and attempt to solve complex problems, the solutions will have to share knowledge. This will inherently imply the need to share data formats, access mechanisms, networking and communication. Oh yes, and don't forget the need to carefully deploy ethical practices in these intelligent systems. Refer to IEEE's 7000 series of standards. This is the emerging field in standardization so important to students, researchers, industry practitioners, and policy makers (among others).

Yatin Trivedi, Editor-in-Chief, is a member of the IEEE Standards Association Board of Governors (BoG) and Standards Education Committee (SEC), and serves as vice-chair for Design Automation Standards Committee (DASC) under Computer Society. Yatin served as the Standards Board representative to IEEE Education Activities Board (EAB) from 2012 until 2017. He also serves as the Chairman on the Board of Directors of the IEEE-ISTO.

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Yatin received his B.E. (Hons) EEE from BITS, Pilani and M.S. Computer Engineering from Case Western Reserve University. He is a Senior Member of the IEEE and a member of IEEE-HKN Honor Society.

The Flourishing Landscape of Robot Standardization

by Theo Jacobs, Jan Veneman, Gurvinder S. Virk and Tamas Haidegger

International standardization in robotics paves the way to the market for new robotic products, assists to overcome technical barriers in international commerce, and fosters market growth. While safety standards form the primary basis to establish specific types of robotic products in helping create new markets through reducing safety risks for users as well as reducing liability risks for manufacturers, other standards can help to dismantle trade barriers such as standards on terminology, coordinate systems, performance benchmarking and inter-operability based modular design. With the rapid rise of new robotic domains, standardization also had to shift gears. As the market for (shared space) robots constantly grows, the demand for standards in this area also constantly rises. Due to the large variety of robot designs and application domains, existing and newly developed standards usually do not cover all robots in general but are limited to certain environments and robot types. An important distinction for standards refers to industrial applications versus medical applications versus other (non-industrial, non-medical, non-military) applications. This article introduces the main robotics-related standardization activities at ISO/IEC.

Introduction

Since the early 1990s, Standard Development Organizations have been releasing robotics standards. Yet, given the unprecedented pace of advancement in this field, SDOs are in a very challenging position to regulate rising domains which evolve much faster than the traditional creation cycle of a technical standard. The first IEEE robotic standard came out late (P1872, 2015), born into a rapidly evolving robot standardization environment, mostly outlined by the work of the International Organization Standardization (ISO) and International Electrotechnical Commission (IEC). It is important to recognize the work that has been done by these SDOs, and review the current hot areas to better understand the landscape of robot standards.

Different SDOs adopt different approaches to fill the existing gaps. While ISO has one central standardization committee, TC 299 (Technical Committee) for robotics, IEC relies on a distributed structure, where robotic standards are mainly developed by TCs and SCs (Subcommittees)of various application domains, such as lawn mowers and household appliances. However, IEC has created an Advisory Committee on Applications of Robotics Technology (ACART) to coordinate robot standardization activities within ISO and IEC. International (safety) standards are based on reaching consensus among the participating countries. Working groups are open to all interested stakeholders from industry, academia and general society including manufacturers, integrators and professional end users

The largest number of robot-related standards has so far been developed by the ISO TC 299 Robotics, that groups all ISO standardization activities related to robotics, including diverse liaisons with IEC on medical robotics. The current structure of this TC, its (joint) working groups, chairs and main activities are summarized in Figure 1. Further information on TC299 is available on the ISO website. The current activities of the TC and the Working Groups (WGs) within are detailed *at the top of the next page.*

Progress in WG 1 – Vocabulary and characteristics

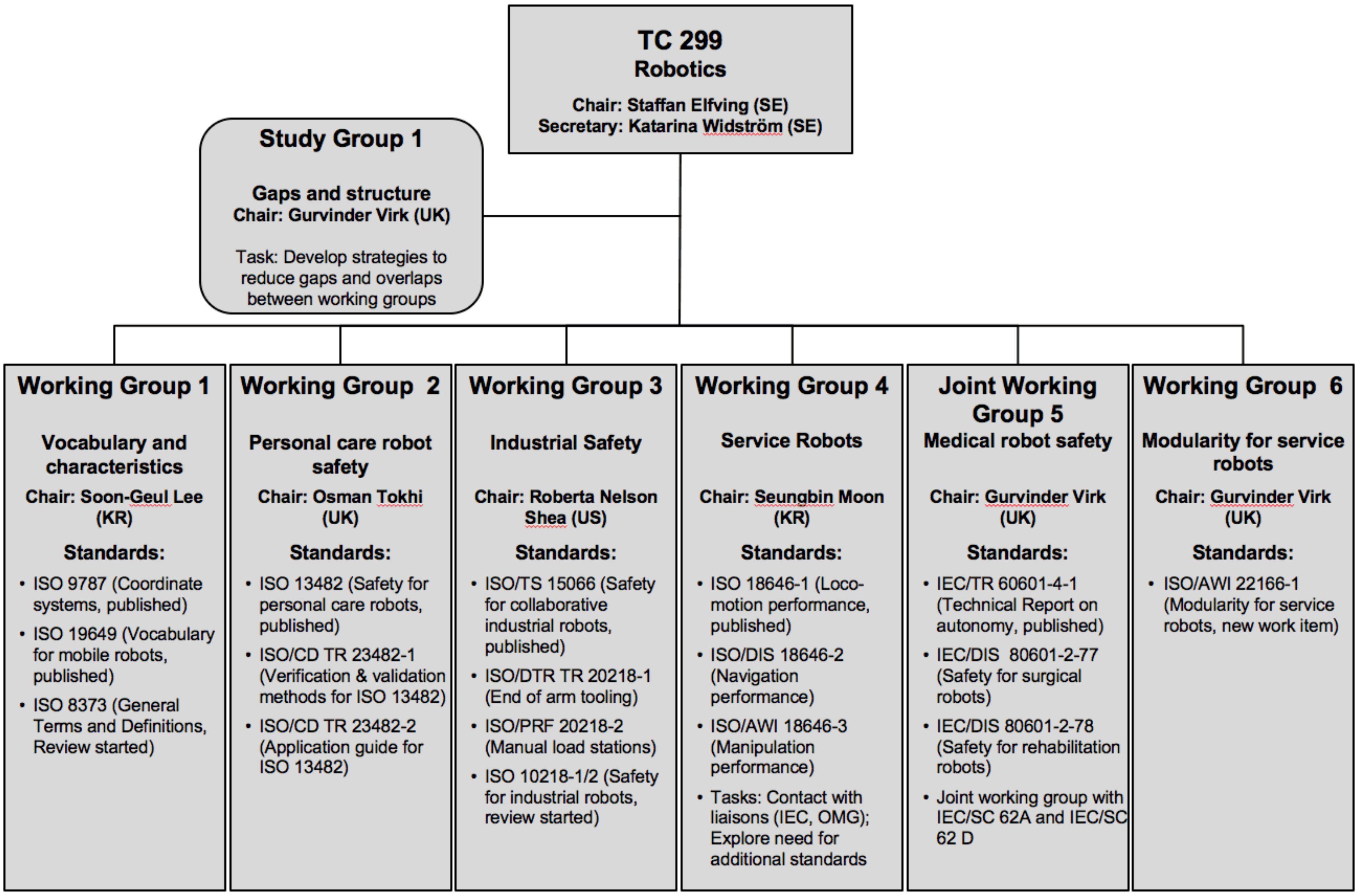
Chair: Soon-Geul Lee (Kyung Hee University, South Korea)

Standards:

- ISO 9787 – Robots and robotic devices – Coordinate systems and motion nomenclatures (published in 2013)
- ISO 19649 – Robots and robotic devices – Vocabulary for mobile robots (published in 2016)
- ISO 8373 – Robots and robotic devices – Vocabulary (published in 2012, scheduled for periodic review)

WG 1 is maintaining robot-related definitions and terminology which are used in the different working groups in TC 299. Fundamental definitions are the terms "robot", "robotics", "robotic technology" and "autonomy" which are used in the title and scope of the robotics standardization committee. As especially the market for service robots is still emerging, these definitions are not considered to be final, but are expected to be adjusted from time to time as necessary. With the recently initiated review process of ISO 8373, WG 1 will coordinate a systematic review of the definitions with the goal to ensure that the terminology is fit for future standards and working groups. This will also include a categorization of robots based on their mechanical structure,

ISO Standardisation committee TC 299



task and application domain which will allow the exact shaping of scopes for standards and working groups.

Apart from basic terminology, WG 1 is dealing with other vocabulary for certain domains such as navigation or perception and has published ISO 19649 in the beginning of 2017. The standard defines terminology for mobile robots such as the definitions of wheel types and undercarriage structures. During the last meeting in Suzhou WG 1 has started the revision of ISO 8373.

Progress in WG 2 – Personal care robot safety
Chair: Osman Tokhi (London South Bank University, United Kingdom)
Standards:

- ISO 13482 – Robots and robotic devices – Safety requirements for personal care robots (published in 2014)
- ISO/CD TR 23482-1 –Technical report: Validation criteria for personal care robots (committee draft)
- ISO/CD TR 23482-2 – Application guide for ISO 13482 to be published as a technical report (committee draft)

WG 2 has the task to develop safety standards for "personal care robots" – earthbound robots in direct interaction with the human and contributing directly to his/her well-being. Three robot types representing the personal care robot, "mobile servant robots", "person carrier robots" and "physical assistant robots" were identified and serve as examples in the standard ISO 13482. With respect to the special situation that personal care robots act in direct vicinity of the user and that the autonomy of these robots is generally high, some clauses were added, that are unique in machinery safety, such as instructions dealing with incorrect autonomous actions and decisions.

During the last meeting in Suzhou, the working group continued developing two guidance documents which will help manufacturers to apply the standard and to verify compliance of their products. In the technical report ISO TR 23482-1 that is currently under preparation, measures for verification and validation are described which can be used by robot manufacturers for safety testing. Tests include stability tests for different travel patterns (e.g. on ramps or while accelerating or stopping), but also impact tests with crash test dummies. A second technical report, ISO TR 23482-2, provides guidance on how to perform risk assessment and risk reduction for personal care robots.

When these two technical reports are published, WG 2 will start the systematic review of ISO 13482. Most likely this will include splitting up the standard into several parts, so that each robot type can be maintained in a separate document and new robot types can easily be added.

Progress in WG 3 – Industrial safety
Chair: Roberta Nelson Shea (Universal Robots Inc., USA)
Standards:

- ISO 10218-1 – Robots and robotic devices – Safety requirements – Part 1: Robots (published in 2011, periodic review started)
- ISO 10218-2 – Robots and robotic devices – Safety requirements – Part 2: Robot systems and integration (published in 2011, periodic review started)
- ISO TS 15066 – Robots and robotic devices – Safety requirements for industrial robots – Collaborative operation (published in 2015)
- ISO/DTR TR 20218-1 – Robots and robotic devices – Safety requirements for industrial robots – Part 1: Industrial robot system end of arm tooling (end-effector) (new work item)
- ISO/PRF 20218-2 – Robots and robotic devices – Safety requirements for industrial robots – Part 2: Industrial robot system manual load stations (committee draft)

WG 3 is dealing with the safety of industrial robots. After the technical specification ISO TS 15066 which provides extended requirements for human–robot collaboration and specifies limits for impact forces and pressures, WG 3 developed two new work items. One is a technical report on the safety of manual load stations, i.e. stations where a worker hands over a part directly to a robot end effector (e.g., a gripper). In addition, a guidance document is developed on the safety of industrial robot end effectors.

WG 3 is also in the process of doing a systematic review of ISO 10218-1 and -2 which have now reached an age of 5 years. During the update process, it is intended to integrate content from ISO TS 15066 into these standards.

Progress in WG 4 – Service robots
Chair: Seungbin Moon (Sejong University, South Korea)
Standards:

- ISO 18646-1 – Robots and robotic devices – Performance criteria and related test methods for service robot – Part 1: Locomotion for wheeled robot (publication by the end of 2016)
- ISO/DIS 18646-2 – Robots and robotic devices – Performance criteria and related test methods for service robot – Part 2: Navigation (committee draft)
- ISO/AWI 18646-3 – Robots and robotic devices – Performance criteria and related test methods for service robot – Part 3: Manipulation (new work item)
- Add. Task: Determining need for additional standards for service robots

WG 4 is engaged in developing standards on robot performance. In order to compare the performance of functions like path-finding, object recognition or the ability to move on difficult terrain, standardized test methods are necessary. The first standard, ISO 18646-1 for measuring locomotion performance, was published in 2016. The second part, ISO 18646-2 on navigation performance is also close to publication and includes e.g. test setups for measuring path repeatability of the turning width of a mobile robot. A third part dealing with manipulation performance is has recently been started. In addition, WG 4 has since many years the special task to monitor the development on the service robot market in order to identify the need for additional standards for service robots. In the last years, several liaisons have been established with IEC, because the development of standards for autonomous vacuum cleaners and lawn-mowers has been initiated there.

Progress in JWG 5 – Medical robot safety
Convenor (ISO): Gurvinder Virk (CLAWAR Association, United Kingdom)

Convenor (IEC): Michel Brossoit (CSA Group, Canada)
Project leaders:

JWG 35 (IEC numbering) – Medical robots for surgery: Kiyoyuki Chinzei (AIST, Japan)

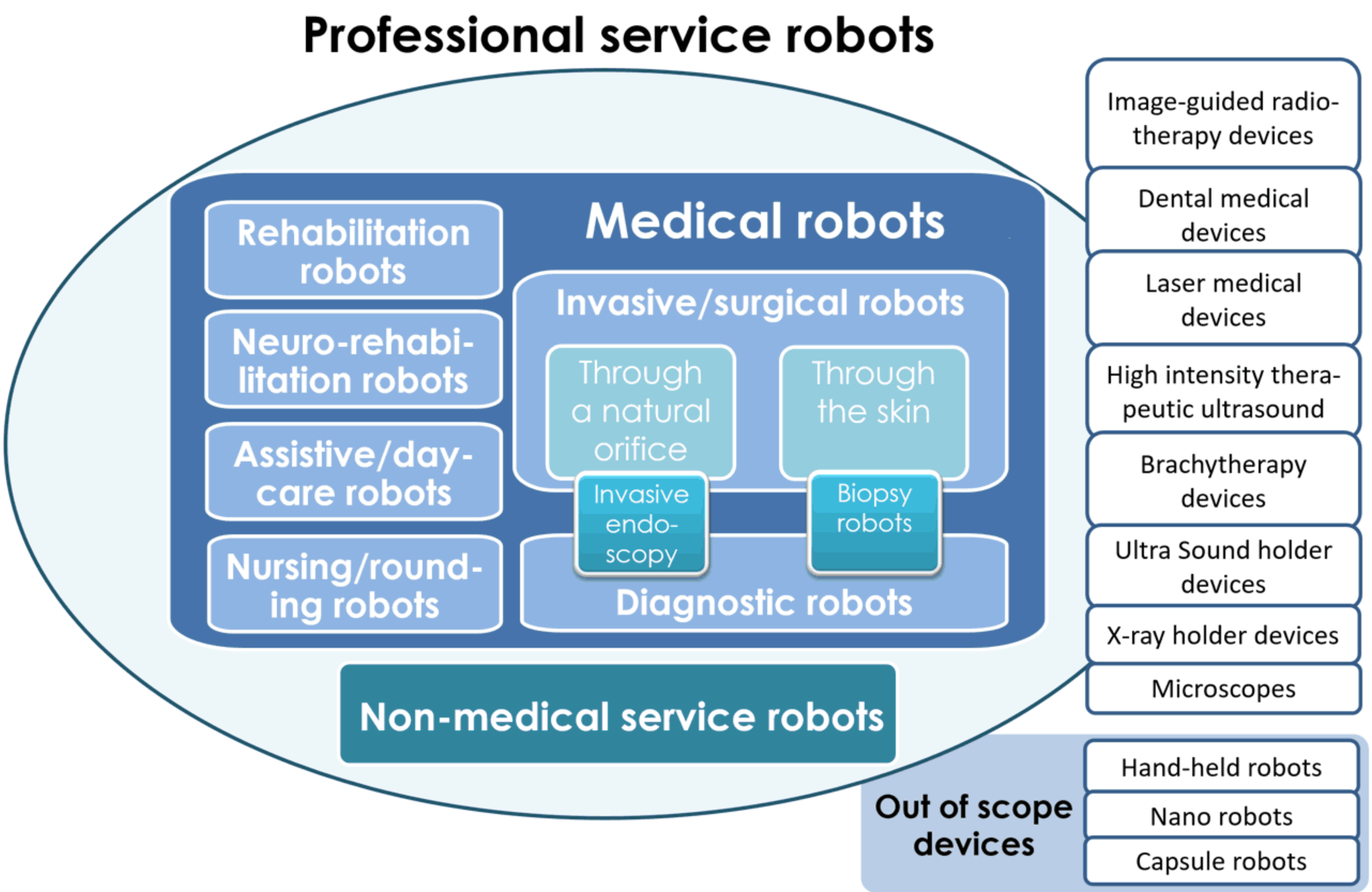
JWG 36 (IEC numbering) – Medical robots for rehabilitation: Burkhard Zimmerman (Hocoma AG, Switzerland)

Standards:

- IEC/TR 60601-4-1 – Medical electrical equipment – Part 4.1: Guidance and interpretation – Medical electrical equipment and medical electrical systems employing a degree of autonomy (published)
- IEC/DIS 80601-2-77 – Medical Electrical Equipment – Part 2-77: Particular requirements for the basic safety and essential performance of medical robots for surgery (committee draft)
- IEC/DIS 80601-2-78 – Medical Electrical Equipment – Part 2-78: Particular requirements for the basic safety and essential performance of medical robots for rehabilitation, compensation or alleviation of disease, injury or disability (committee draft)

Other than industrial robots and (non-medical) service robots, robots used for healthcare purposes have to fulfil safety requirements for medical devices instead of or in addition to requirements for machinery safety. With this possible conflict in mind, a joint working group (JWG) between ISO TC 299 (responsible for robot safety) and IEC SC 62 A (responsible for medical electrical equipment safety) was founded in 2010. The JWG spent quite some time on evaluating the boundaries and requirements for the new standards. As a first result, a technical report providing guidance on medical equipment with autonomous functions, ISO 60601-4-1 was published in 2017. The committee outlined the various sub-domains of medical robots being affected by the new standards.

The current domains of medical robots, as derived from the IEC 60601:2015 medical electrical equipment and the ISO 8373:2015 robot vocabulary standards



In 2015, two subgroups were founded inside JWG 5 with IEC SC 62D. The first subgroup (JWG 35) is developing a standard for basic safety and essential performance of robots for surgery, IEC 80601-2-77. The second subgroup (JWG 36) is dealing with medical robots used for rehabilitation and has started the development of IEC 80601-2-78. Recently, in 2017, both documents have reached the status of Draft International Standards (DIS), now being circulated for final voting among member states.

Progress in WG 6 – Modularity for service robots
Chair: Gurvinder Virk (CLAWAR Association, United Kingdom)

Co-Chairs: Shuping Yang (RIAMB, China), Hongseong Park (Kangwon National University, South Korea)

Standard:
ISO WD 22166-1 – Robotics – Part 1: Modularity for service robots – Part 1: General requirements WG 6 has the task to prepare the development of a new standard for interoperability and reusability of robotic components on mechanical, electrical and software levels. WG 6 is currently working on its first work item to create safety requirements and guidance for service robot modularity. The goal of the standard is to provide guidance to manufacturers who want to develop their own modular architecture. Key sections being developed include

Definitions
- Generic modularity issues (including connectivity, interoperability and safety at the module level)
- Safety and security issues of modular systems
- Frameworks for hard- and software
- Key robotic components

During the last meeting in Suzhou, the working group finished a series of changes originating from the new work item balloting and prepared the document for the committee draft ballot.

Apart from these, ISO is continuously looking into the revision and amendment of its existing robot standards, and looking into co-operations to align with similar domains (e.g., standards for self driving cars, currently guided by vehicle standards within ISO). One prime example for that is the establishment of the SG1 (study group 1), which is solely focusing on the gaps and inconsistencies between the output of the existing WGs, so their future work can be better focused and streamlined.

Conclusion and outlook

It is clear that robotics is evolving from its industrial manufacturing roots at an increasing rate and new robot use cases are emerging. The new robot application sectors are posing new challenges for standardization and ISO and IEC have reacted rapidly over the past 10 years or so to create new working groups to develop the needed standards, especially those related to safety. The foremost aim of international standardization is to facilitate the exchange of goods and services through the elimination of technical barriers to trade. The process of standardization, and especially the organization of the working group meetings is a voluntary effort of the international experts devoted to robotics, where international peers from the Academia, Industry and Government can work together toward clear targets. With the increasing usage of robots, the needs for standardized solutions has intensified. The focus of ISO TC 299 is to identify and address these needs related to all robotics disciplines, preferably in a collaboration with other SDOs and professional organizations, like IEEE. The new robot domains are giving rise to boundary and overlap issues and where one type of robot ends and another starts; for example when does a physical assistant exoskeleton robot governed by WG2 become an industrial robot governed by WG3. SG1 has recently been set up address such issues and help provide recommendations on how to organize future robot standardization projects. Also gaps in robot standardization projects are to be identified.

Acknowledgment

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About the authors

Theo Jacobs received his degree in Mechanical Engineering from Leibniz University Hannover in 2008. Since then he is working as project manager at Fraunhofer IPA, focused on mechanical engineering in the field of mobile service robots for industrial and domestic use as well as the safe design of such robots. Since 2009 he is a technical expert in the ISO standardization committee TC 299 where he is engaged in the development of standards for service robots. Since 2014 Theo Jacobs is responsible for the dissemination of standardization results and attraction of new technical experts within the European Coordination actions euRobotics (FP7), RockEU (FP7) and RockEU 2 (H2020).

Jan Veneman, received his degrees from the University of Twente, in Mechanical Engineering (MSc 1999), PSTS (MSc 2002), and Biomedical Engineering (PhD 2007). Currently he works in the Medical Robotics Application Area of the Health Division, Tecnalia Research, and Innovation, Spain. He is project manager and senior researcher on rehabilitation robots and wearable robots. Since 2013 he is coordinating the EC-FP7 consortium research Project BALANCE, on the development of a robotic exoskeleton with self-balancing control. He was elected Action Chair of COST Action 16116 on Wearable Robots and is active since 2012 as national delegate in several ISO and IEC standardization working groups related to medical robotics, especially exoskeletons.

Gurvinder S. Virk received BSc in Electronics Engineering from University of Manchester and a PhD in Control theory from Imperial College, University of London, UK. His current research interests are in personal care robots, wearable exoskeletons, medical robots, climbing and walking robots, robot safety standardisation, and robot modularity. He is Technical Director of Innovative Technology and Science Limited and Trustee of CLAWAR. He has held senior academic positions in UK (Universities of Bradford, Portsmouth and Leeds), Sweden (University of Gavle and KTH), New Zealand (Massey University) as well as visiting positions in China (Zhejiang University), France (Université Pierre et Marie Curie, Paris), Germany (Fachochschule Südwestfalen, Soest) and India (IIT Ropar). He has produced over 350 publications in these areas, supervised 16 successful PhD students, as well as secured external research funding of over $25M. He is a leading actor in international robot standardisation and holds several leadership positions in several robot standardisation groups. He is on the Editorial Board of several scientific journals including Industrial robot, Robotics and autonomous systems, Intech International Journal of Advanced Robotic Systems, and ISRN Robotics, Advances in robotics and automation and Journal of Robotics and mechanical engineering research.

Tamas Haidegger, received his degrees from the Budapest University of Technology and Economics (BME) in Electrical Engineering and Biomedical Engineering (MS EE 2006, MS BE 2008, PhD EE, 2011). His main field of research is control/teleoperation of surgical robots, image-guided therapy and supportive medical technologies. Currently, he is an associate professor at the Óbuda University, serving as the deputy director of the Antal Bejczy Center for Intelligent Robotic. Besides, he is a research area manager at the Austrian Center of Medical Innovation and Technology (ACMIT), working on minimally invasive surgical simulation and training, medical robotics and usability/workflow assessment through ontologies. Tamás is an active member of various other professional organizations, including the IEEE Robotics an Automation Society, IEEE SMC, IEEE EMBC and euRobotics aisbl. He is a national delegate to an ISO/IEC standardization committee focusing on the safety and performance of medical robots.

Networked Rescue Robots: Standards Pave the Way From Prototypes to Deployments

by Christian Wietfeld

The field of rescue robotics has seen many innovations in recent years, especially unmanned aerial systems (UAS) have proven their benefit in emergency situations by providing situational awareness through flexible and fast exploration. But also ground and underwater robots have been deployed in various incidents. Wireless communication systems are essential for enabling the coordinated action of teams of robots, which may originate from different vendors and rescue organizations. Therefore the standardization of communication interfaces as well as data formats will become a major focus in upcoming years. While safe remote operation of rescue robots needs to be enabled by highly reliable so-called control and non-payload communication, the gathering of sensor data (e.g. high resolution video streams) requires high-bandwidth multi-media communication. Rescue robots may not only act as sensor platforms but also as communications relays to provide communication links to rescue personnel and victims on the ground or water surface (e.g. in case of tele-medicine services in maritime rescue scenarios as being currently explored in the collaborative research project LARUS, which is funded by the German Federal Ministry of Education and Research). In this context the on-going standardization for 5G systems are particularly relevant in the area of ultra-reliable low latency communications (URLLC) as well as Enhanced Mobile Broadband (eMBB).

The tight regulatory requirements for the operation of unmanned aerial systems in so-called beyond-line-of-sight conditions call for certified reliability of the communication links. Challenges to be tested are for example: range limitations, interference by object causing shadowing and multi-path fading, as well as active interference by other users, in particular in unlicensed bands. In some scenarios, the communication links may be even challenged by intentional as well as unintentional jamming. Despite these communication limitations the robotic systems needs stay in a controlled condition. Potential solution approaches include multi-link communication, which leverages both unlicensed as well as licensed technology (e.g. combinations of LoRa and LTE). In multi-robot environments as well as in case where rescue UAS have to be integrated in the civil air space, standardized smart secondary radar systems will gain importance in the future. They build partially on the evolution of established standards such as ADS-B (Automatic Dependent Surveillance – Broadcast). But as not all UAS will be able to carry their own ADS-B transceiver, the distribution of corresponding positioning data and no-fly zones are expected to be supported also by public cellular networks.

Standardized procedures are required to test the communication links in a reproducible way. The National Institute of Standards and Technology (NIST) has introduced in this context first editions of "Standard Test methods for Response Robots", which include for example test procedures for ground robots using radio communications in Line-of-Sight range and Non-Line-of-Sight Range. These procedures are expected to be complemented in the future to test involving indoor, urban canyon and interference signal environments, for both ground as well as aerial and maritime vehicles.

On application layer, standardized data formats and interfaces are required to enable interoperability for coordinated robot action. As a starting point one might leverage well established format from the automotive industry. Services defined for the interaction of networked automated vehicles on the road (such as the Cooperative Awareness Messages CAM as part of Vehicle-to-Vehicle communications) may be adapted to rescue robotics and complemented by additional robotic-specific command and control data formats. Also the evolution of the Robotic Operating System (ROS) may lead to standardized data formats to support inter-robot communication.

But these developments are yet in an early stage and international efforts are needed to fully leverage the potential of rescue robotics in the future

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Christian Wietfeld is a full professor and head of the Communication Networks Institute at TU Dortmund University. He received his diploma and Dr.-Ing. degrees in electrical engineering from RWTH Aachen in 1992 and 1997 respectively. After holding various positions in industry (Siemens, 1997-2005), he joined the TU Dortmund in 2005. Since then, he initiated numerous research projects on the design and performance evaluation of communication architectures, protocols and services, leading to team of 20 full-time researchers working under his supervision. Prof. Wietfeld's research has been published in around 175 peer-reviewed conference papers, book chapters, contributions to standardization (ITU-T/3GPP/ETSI/OMA) and patents. In 1999 he received an "Outstanding Contribution Award" of ITU-T. Since 2008 he has received 10 Best Paper awards. He is a senior member of the IEEE, editor for the IEEE Wireless Communication Magazine and head of the committee on "Communication Networks and Systems" in the German sister organization of IEEE, ITG. He has co-founded the IEEE GLOBECOM Wi-UAV workshop on Wireless Communications for Unmanned Arial Vehicles together with Prof. J. How (MIT) in 2010. He has a leading role in several UAV-related research initiatives AVIGLE, AIRBEAM and ANCHORS. Currently, he is the coordinator of the German research project LARUS, which aims to develop a UAV-enabled rescue system for maritime emergency incidents. He is a co-founder of various ward-winning start-ups which transfer research results into products and services.

Standardization Activities for Robotic Services

by Koji Kamei

Development and deployment of robotic services for social environment need standardization activities since such services require adaptive and agile configurability. Component oriented technology for robotic functional modules and APIs for such functions are being standardized for a decade. In IEEE, Robotics and Automation Society (RAS) stands for such standardization. Object Management Group (OMG) fosters Robotics DTF (domain taskforce) for this target domain. In ISO, TC299 (robotics) has replaced TC184/SC2 (automation systems and integration / robots and robotic devices), in which WG6 is dedicated for "modularity for service robots."

Robotic services are often developed using multiple robots and sensors in the service environment those are connected via network. They are therefore called networked robots. A standard about abstract architecture of networked robot is published as ITU-T Recommendation Y.4106 (renumbered from F.747.3) defines requirements and functional model for a ubiquitous network robot platform that supports ubiquitous sensor network applications and services. To develop such services, underlying technologies are standardized as follows.

Recently robotic functions become developed on cloud facilities so that they are also called cloud robotics. In such deployment model, to connect robotic functional modules loosely, common component models are required. OMG has published a standard named Robotic Technology Component (RTC) 1.1 in 2011. RTC defines such a component model of robotic functional modules independent from the network communication layer, as an implementation of RTC, RT-Middleware adopts CORBA (Common Object Request Broker Architecture) as its communication platform. ROS (Robot Operating System) is another de facto standard commonly used to develop robot modules. Though ROS itself is not standardized, the next version ROS2 adopts DDS (Data Distribution Service) and DDS-RPC defined by OMG as underlying communication standards.

Representation of data and functions are another target of standardization. OMG RLS (Robotic Localization Service) 1.1 extends representation of coordinate system and position defined in GIS (Geographic Information System) domain to support information used in robotics field such as heading orientation or pose information of physical entities, error estimation and time of measurement. OMG RoIS (Robotic Interaction Service) Framework 1.1 defines representation of component profiles that describe programming interface of robotic functional components and actual definition of 15 basic components to be used in HRI (Human Robot Interaction) domain. IEEE RAS also published two standards, IEEE 1872-2015 Ontologies for Robotics and Automation and IEEE 1873-2015 Standard for Robot Map Data Representation for Navigation. The former defines core ontology for robotics and automation (called CORA) that gives formal representation and reasoning in robots, then being extended to industrial robot and autonomous robotics. The latter provides a common representation and encoding for the map data used for navigation by mobile robots. In ISO, TC299 WG6 works on modularity for service robots to cover both software modularity and hardware modularity with safety aspects. Ontologies for service robots and communication infrastructure for service robots including both messaging and wireless networking will be next issues to be standardized in those organizations.

Those standards are, as a case study, used in an implementation of autonomous mobility system in social environments as follows. Assume a shopping mall as a service environment and numbers of mobile service robots such as navigation robots, carrier assistance robots and wheelchair robots are moving in coordination with pedestrians and providing services offered by the mall, shops in the mall and other information providers. Service providers will hire suitable robots for their target customers to provide service and those robots work for the customer. A common platform is required to manage robotic resources and to establish connection between services and robots. In the case, an implementation of ITU-T Y.4106, named "UNR Platform," is used as a base platform and OMG RoIS is used to define/call components APIs. The functions of those components and side effects in the social environment regarding ethical, legal, social issues (ELSI) in robotics are to be described for reasoning in service execution but not yet standardized; they are to be discussed as a part of robotic service ontology. Integration of messaging (RoIS, CORBA, DDS) layer and mobile networking layer (Wi-Fi, LTE, 5G) are also addressed in the project.

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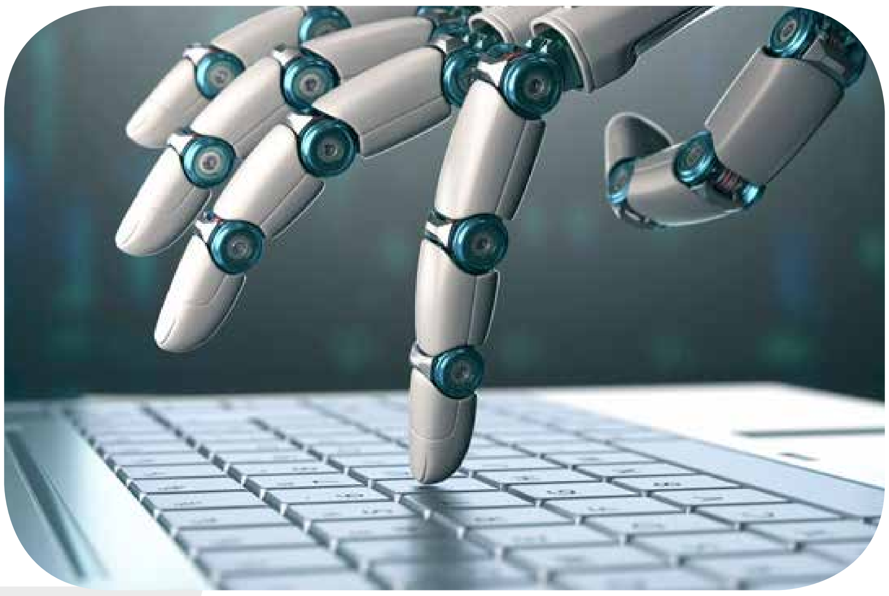
Discover more information about Robotic Standardization

by Rob Craig



With 2018 on the horizon, and so much development and innovation in Robotics, keeping up with the latest news can be overwhelming. Even harder is knowing where the best sites are for informed coverage on Robotics. Thankfully, many excellent resources for Robotics exist within IEEE and online, from industry websites to reference tools and communities, all designed to make the task of understanding the complex and diverse world of Robotics just a little bit easier and more effective.

We've scoured the Internet to share some of the best of these resources, and we hope you'll find lots of valuable content and tools through these incredibly useful links on Robotics that you are encouraged to add to your reading list and which will enhance the content of this month's E-Magazine. These sites are wholly devoted to covering the news, trends and issues within the robotics community. Some of them only look at specific aspects of robotics, such as investment or business, but most of them cover a wide range of robotic news stories from industry to the latest research projects, conferences, and standards.

Enjoy!

About IEEE

What + If = IEEE
This video provides a brief overview of the broad mission of the IEEE. IEEE and its members inspire a global community to innovate for a better tomorrow.

IEEE Standards Help Transform Lives
IEEE develops standards that nurture and advance global technologies and innovations. IEEE members are developing a technology that can help give people all over the world access to modern energy.

Standards

New IEEE Standards for Artificial Intelligence Affecting Human Well-Being
With an increase in artificial intelligence technology being integrated into our world, the IEEE Standards Association has created three new projects that focus on the well being of humans in the creation of autonomous and intelligent technologies.

Ethically Aligned Standards- A Model for the Future
The mandate to provide technologists with a pragmatic guide to deal with the pressing ethical considerations of AI/AS.

Ethics and Standards
What responsibilities do we have for the technologies we create?

Advancing Technology for Humanity – the Human Standard & AI
What does it mean to Advance Technology for Humanity?

7000 – Model Process for Addressing Ethical Concerns During System Design
Engineers, technologists and other project stakeholders need a methodology for identifying, analyzing and reconciling ethical concerns of end users at the beginning of systems and software life cycles.

IEEE Std 1872-2015 – IEEE Standard Ontologies for Robotics and Automation
A core ontology that specifies the main, most general concepts, relations, and axioms of robotics and automation (R&A) is defined in this standard.

1872.1 – Robot Task Representation
The purpose of the standard is to provide a robot task ontology for knowledge representation and reasoning in robotics and automation.

1872.2 – Standard for Autonomous Robotics (AuR) Ontology
The purpose of the standard is to extend the CORA ontology to represent more specific concepts and axioms that are commonly used in Autonomous Robotics.

Standards: The Path to Industry Engagement – Don Wright – Ignite: Sections Congress 2017
Don Wright, President of both the IEEE Standards Association and Standards Strategies LLC, speaks about enabling communications through standards. These standards for industry cover power and energy, computation, healthcare, Internet and even Artificial Intelligence.

Articles

AI Startup Embodied Intelligence Wants Robots to Learn From Humans in Virtual Reality
Embodied Intelligence wants to use AI and VR to teach robots new skills, like how to manipulate wires, much faster.

Robots for Kids: Designing Social Machines That Support Children's Learning
TEGA, a social robot built to teach children

The 1961 Mobot Mark II Had All the Moves
Billed as a "Replacement for Man," the Hughes Mobot combined strength with a delicate touch

IEEE Global Initiative Aims to Advance Ethical Design of AI and Autonomous Systems
Reports on the scope, goals, and initiatives of the IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems.

Using Artificial Intelligence to Land Drones on Moving Platforms
The next big goal in unmanned aerial vehicles (UAVs) is to make them fully autonomous

Selecting the Best Power Source for Giant Robots
Aside from research by NASA, who is investigating the feasibility of harnessing energy from antimatter reactions, powering a robot on the scale of science fictional characters like the Iron Giant or Voltron is nearly impossible.

New Industrial Robotics Standards Body
The U.S. Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have partnered with the Robotic Industries Association (RIA) trade group to set standards for industrial robotics.

Lethal Microdrones, Dystopian Futures, and the Autonomous Weapons Debate
In "Slaughterbots," a film created by a group of academics concerned about lethal autonomous weapons, swarms of explosive-carrying microdrones are used to kill thousands of people.

This Robot is Designed for Disaster Relief
With the increase in occurrences of natural disasters like hurricanes, tornados and fires, there is a real need for technology that can help with relief efforts.

A Robotic Arm That Knows Sign Language
While robots are being taught all sorts of crazy skills to help humans, graduate students at the University at Antwerp in Belgium have designed a robotic arm that can perform sign language.

A top engineer says robots are starting to enter pre-K and kindergarten alongside kids
Tiny humans aren't the only ones entering a classroom for the first time in the fall.

Mixed Reality Research at NYU Brings Robots Under Control With a Smartphone Swipe
In conventional industrial automation, robots are programmed to perform very specific tasks, such as on an automobile assembly line. More recently, machine learning has emerged to help robots and self-driving cars to react more flexibly to their environments.

The Future of Cobots: Adaptive Thought Control
Cobots are now so integrated into business that it's something of a cliche to compare this new generation of automation to the clumsy, cage-bound robotics common two decades ago.

Top 5 Robotics and AI Trends for Businesses to Look for at CES 2017
Robotics businesses shouldn't be deterred by the hype and consumer focus, though; some robotics and AI trends emerging here will apply across industries in the coming year.

Can Techie Parents Reinvent School For Everyone–Or Just Their Rich Kids?
Silicon Valley veterans are ditching fast-track careers and going all-in with their time and money as they reimagine education for their children.

This Robot Swarm Finishes Your Grocery Shopping In Minutes
Ocado's warehouse technology would probably make Jeff Bezos green with envy.

Call for Papers

SPECIAL ISSUE in IEEE Transactions on Cybernetics
From Intelligent Control to Smart Management of Cyber-Physical-Social Systems: A Celebration of 70th Anniversary of Cybernetics by Norbert Wiener

IEEE Transactions on Cognitive and Developmental Systems: Special issue
IEEE Transactions on Cognitive and Developmental Systems

Special issue on: "Introspective Methods for Reliable Autonomy"

Submission deadline: 31 January 2018

Ubiquitous Robots 2018
Robotics is the ultimate interdisciplinary field, and Ubiquitous Robots invites contributions from the entire foundational spectrum—design, perception, manipulation, interfaces, mobility, intelligence—and application domains—industrial, social, transportation, medical, rehabilitation, healthcare, agriculture, construction, security, disaster, and other applications.

Competitions

World Robot Olympiad

Starting in 2004, World Robot Olympiad has developed to a truly global competition. WRO tournaments are organized in more than 60 countries and each season new countries join the movement. The WRO international final in November is hosted by a different country each year.

Robothon

Robothon is a robotics challenge sponsored by MINDS-I in the Seattle area. Its events include RoboMagellan, Line Following, Line Maze, Minisumo, and 3kg Sumo. Robothon is a national event that showcases the capabilities and technological developments in robotics from the amateur robotics community.

VEX VRC & VEX-IQ

Innovation First International (IFI) founded the VEX VRC and VEX-IQ competitions for students at all levels. These programs are implemented largely in the education market. Educators and schools order robots and robotics products from VEX.

FIRA RoboWorld Cup

FIRA is most for above BA/BS level students and companies to develop their research in robotic field though robot soccer.

International Robot Olympiad

IROC is for students from under 8 to undergraduate students. It has been one of most popular robot competition for a decade.

National Robotics Challenge

Engineering is not just about taking the same parts as someone else and changing how they are put together. Engineering is about finding the materials and equipment that is best for the problem you are given.

Communities & Blogs

Robohub

As the name suggests, Robohub is a hub for all things robotics. Blogs are posted several times a day. For anyone interested in reading about robotics from knowledgeable people within the industry, this is definitely a site to check out.

Robotics.org

The Robotics Industries Association posts almost every day. They have a news stream, which releases the latest from the robotics industry, and an Industry Insights stream, where they take a considered look at some of the issues behind robotics.

Robotics Industry News, Applications and Trends @ Robotiq

News stories every week about robotics with the majority of coverage about collaborative robots and the technical issues surrounding robotics.

IEEE Spectrum – Automaton Blog

The IEEE Spectrum is the magazine of the Institute of Electrical and Electronics Engineers. The online Automaton blog also publishes frequent news stories relating to robotics and automation.

Conferences

IROS 2018

Towards a Robotic Society| October, 1-5, 2018, Madrid, Spain

IRC 2018- IEEE International Conference on Robotic Computing

The second IEEE International Conference on Robotic Computing (IRC 2018)

Interactive Content

Generation AI

The next generation of children — those born to Millennials — will have artificial intelligence (AI) technologies infiltrate nearly every aspect of their lives, from infancy to their golden years. Follow the IEEE AI timeline below to see how Generation AI will be impacted by technology in each stage of life, as they grow up and balance emotional independence with technological interdependence.

Robotics: Interactive Impact Map

Interactive map of world robotics

Hollywood Takes on AI

Interactively explore AI in Hollywood movies

Learning Opportunities

Ethics in Standards Development and Application

Understand the role ethics plays in standards development and application as well as what questions to ask when deciding whether or not a decision is ethical.

SLAM, Simultaneous Localization and Mapping

This course covers the general area of Simultaneous Localization and Mapping (SLAM). Initially the problems of localization, mapping, and SLAM are introduced from a methodological point of view.

Engineering Ethics: Ethical Challenges for Robotic and Automation Engineers

Tutorial designed to introduce engineers who work in the fields of robotics and automation to ethical considerations and codes of ethics.

Webinar: Ethically Aligned Design: Prioritizing Wellbeing for Artificial Intelligence and Autonomous Systems

The IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems released the first version of its document, Ethically Aligned Design (EAD) on 13 December 2016.

Podcasts

Nick Bostrom Says We Should Trust Our Future Robot Overlords

Is artificial intelligence likely to make humans extinct, or are we smart enough to control it?

IBM's Watson Tries to Learn…Everything

What happens when Watson learns a million databases? RPI students and faculty hope to find out

Robohub

Videos

How to Build a Moral Robot

If robots are going to drive our cars and play with our kids, we'll need to teach them right from wrong

Soft, Printable, and Small: An Overview of Manufacturing Methods for Novel Robots at Harvard

Surgical Robotics presentation 2014 IEEE/RSJ International Conference

Bioinspired Multimodal Flying Robots

Robotics presentation at IROS Conference 2014

Development of Neural Interfaces for Robotic Prosthetic Limbs

Robotics presentation at IROS Conference 2014

Robots and Gaming – Therapy for Children with Disabilities

Robotics presentation at IROS Conference 2014

Human-Guided Video Data Collection in Marine Environment

Marine and space robotics presentation at IROS Conference 2014

How Robots Learn—A Video Series

From manufacturing and entertainment to driving, robotics is one of the most exciting and evolving fields of technology. While engineers have historically programmed robots to complete specific tasks, robots are now being taught to learn on their own.

Meet Saudi Arabia's Newest Citizen – Sophia the Robot

Sophia, the humanoid robot, has been granted citizenship by Saudi Arabia.

Websites

Robotics.org

The Robotics Industries Association releases the latest from the robotics industry, and an

Industry Insights stream

, where they take a considered look at some of the issues behind robotics.

RoboGlobal News

Presents quick roundups of the latest headlines in robotics and occasional posts, RoboGlobal covers robotics from an investment perspective. Primarily, the site tracks trends in robotics stocks, while their blog posts look at overall trends in robotics.

Robotics Business Review

The Largest, most comprehensive online robotics news and information resource, which regularly posts about all aspects of the business of robotics.

The Robot Report

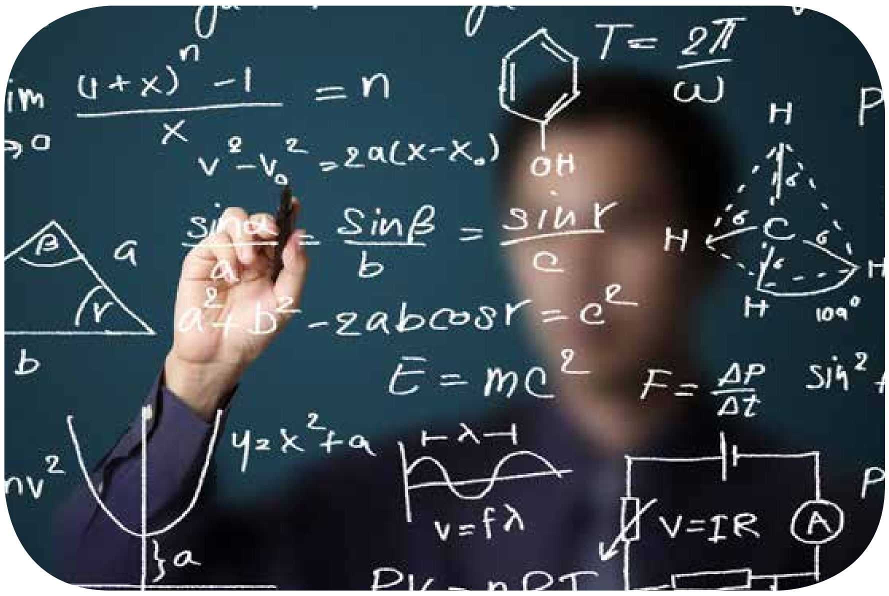
Written by roboticist, Frank Tobe, cofounder of Robo-Stox, a tracking index for the robotics industry. Aims to follow the business of robotics and regularly reports on developments from all areas of the robotics industry.

AUVSI

The world's largest nonprofit organization devoted exclusively to advancing the unmanned systems and robotics community.

Teaching Standardization in Engineering, Science, and Technology Studies

by Tineke M. Egyedi



For the author, Dr. Tineke M. Egyedi, director-researcher of the Delft Institute for Research on Standardization (DIRoS), the challenge to create interest in standardization and communicate the relevance of standards to students and policy makers inspired her to initiate 'Setting Standards', the first management simulation game on standardization. In this article, Dr. Egyedi discusses the standardization games she developed in collaboration with United Knowledge, a company with vast experience in developing policy games, in addition to her current work in the field of standardization.

About the Delft Institute for Research on Standardization (DIRoS)
DIRoS, founded in 2012, initiates and executes scientific research on standardization-related issues for public and private organizations. The mission of DIRoS is to contribute towards raising societal and policy awareness about, and interest in, the relevance, workings, and consequences of standardization, and furthering scientific insight in this area.

Apart from basic and applied research (e.g., on standardization processes, strategies, mechanisms, impact, and policies), consultancy and policy analysis (e.g., Dutch Court of Audit), and publications (academic, policy reports, and writings to stimulate public debate), DIRoS' activities include:

- Raising awareness and interest (e.g., Tales of Standardization and Game Development with United Knowledge)
- Education (e.g., MOOCs, lectures, and workshops)
- Contributions towards building an academic standardization community (education and research; e.g., EURAS)

Using Games to Teach Standardization in Technical and Non-Technical Courses and Train Professionals
Since 2009, when the management simulation game Setting Standards was launched, it has been incorporated into academic courses worldwide (e.g., safety science and innovation management), by government agencies, policy makers and associations (e.g., NIST, Dutch cadaster, European trade union confederation), and as a tool to train standardizers (e.g. Chinese ISO standardizers). More recently, United Knowledge and DIRoS developed three additional games for the Danish Standards Body (DS) for teaching standardization in different academic disciplines (engineering, business management, law, sociology, etc.).

Setting Standards: **A simulation exercise on strategy and cooperation in standardization**
Setting Standards was developed to show students, practitioners, and policy makers why standardization is highly interesting, important and "fun" to study. The game was originally designed for 12–25 people and to take about 6 hours (lunch included). It can be used as a stand-alone or integrated module. For example, a professor in safety science started out with an introductory lecture on the relevance of standardization in her field before proceeding with the game.

It should be noted that Setting Standards requires no prior knowledge of standardization. Participants learn by doing by means of role-playing. Through the course of the game, they gain hands-on experience in how standardization works, simultaneously gaining insight into underlying mechanisms and dilemmas, the role of procedures, and how these may play out.

After role-playing, the group reflects on what happened and applies theoretical frameworks to analyze the different strategies used. While simulations necessarily simplify reality, experts rate Setting Standards as being highly realistic (see Erik Puskar's review and participant reviews on the game's website).

Danish Games for Academic Education on Standardization
In 2014, United Knowledge and DIRoS developed the three simulation exercises for the Danish Standards Body (DS) presented below. These simulations were designed to introduce Danish students in engineering, sociology, economics, law, business management, etc. to standardization in a playful but serious way. The exercises set out to raise student awareness, trigger interest and increase understanding of what standards are, how they are developed and their possible effects. Each simulation game takes between one and two and a half hours and can be played with up to 25 (sometimes 50) participants. These simulations also require no prior knowledge of standardization.

***Good teaching!* – the meaning of standards**
With the learning goal of understanding what standards are, what they are for, and how they are developed as a consensus building processes, participants work in groups to develop a standard for "good teaching." A framework is employed to help participants understand the conceptual differences between various kinds of standards and different approaches to standardization. For this activity, 60 – 90 minutes is traditionally allocated.

***The Sky's the Limit* – standards and innovation**
In this game, next to understanding what standards are and how they are developed, the learning goal shifts to an understanding of how standards in general—and regulatory standards in particular—may hinder or enhance innovation. Participants negotiate a few simple rules that would be needed if a new invention, the Autocopter, became a commodity. An analytic framework is used to help understand the conceptual differences between prescriptive and performance standards and an exploration of their effects on innovation is explored. For this activity, 90 – 120 minutes is traditionally allocated.

Allprod Incorporated **– standardization as a business strategy**
The final simulation game challenges participants to understand how standards may influence the competitiveness of a business as well as competition in the market. Participants play the role of board members of a company active in diverse markets. Working in small teams they make and discuss a series of business decisions. Each decision is evaluated on how it may impact the company's future. For this simulation, participants are allocated 120 – 150 minutes.

While the three games above were designed for a limited number of students, Tineke recently experienced that it was appropriate to include The Sky's the Limit with slight adaptations as part of a lecture series for 120 masters students (Tilburg University). Whether this is also possible for the remaining games, has yet to be assessed in formal application.

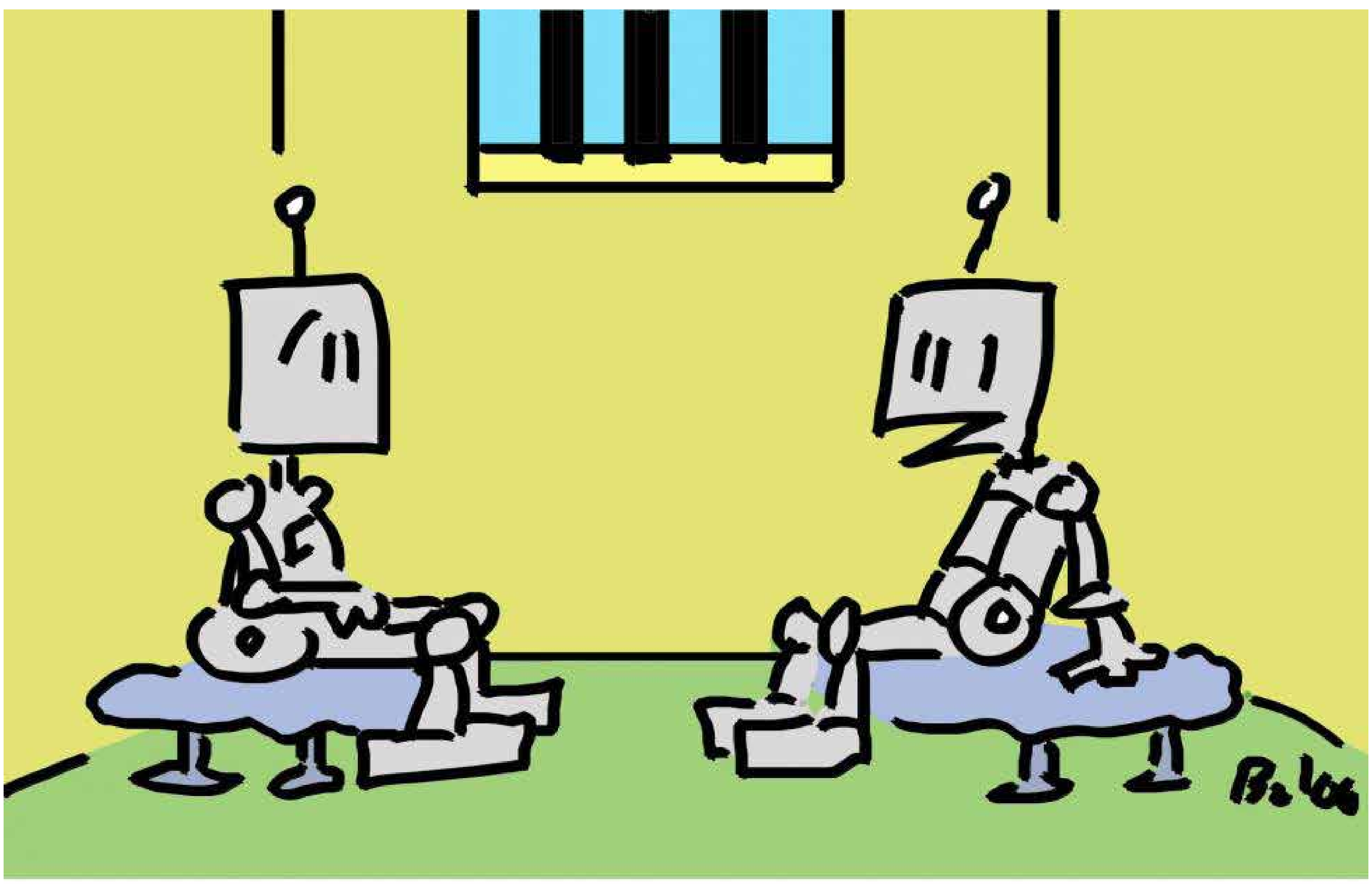
Evaluations by game participants indicate that, apart from being a useful and involving learning tool, the games are a powerful vehicle for creating interest in and communicating the relevance of standardization. Tineke also believes that they can be a powerful tool for disseminating novel research insights, and feels challenged to translate her research findings into innovative simulation games.

Dr. Tineke M. Egyedi is founder and director-researcher of the Delft Institute for Research on Standardization (DIRoS). Her current activities focus on how standards and regulation affect innovation and include, for example, a study on the valuation of patents in standardization (Intel research grant) and on the constraints of standards, rules and regulations as perceived by people working in care for the elderly (Magentazorg). With dr. Roland Ortt she developed a new functional classification of standards for the Handbook on Innovation and Standards (edited by Hawkins et al., 2017). Her most recent lecture was for students at the Tilburg Institute of Law and Technology.

From January 2000 to March 2015, Tineke worked as a senior researcher at the Delft University of Technology. She has published in journals ranging from IEEE Communications Magazine to International Journal of Hydrogen Energy. Tineke developed MOOC modules on "Inverse Infrastructures" (DelftX: NGI101x), based on the book Inverse Infrastructures: Disrupting Networks from Below (2012; co-edited by Donna Mehos); and on "Standards and Infrastructure Flexibility" (DelftX: NGI102x). She is a former board member of the European Academy for Standardization (President 2005-2011), and currently associate editor of the International Journal of Standardization Research, Funny Pages

Robot Laws

by ©Baloo, Jantoo.com



"No kidding? — you broke all *three* laws of robotics?"