Topic Group “Industrial Robots”

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Introduction

The euRobotics aisbl works to bring industry, academia and applied research together to jointly advance the field of robotics. Three main ways to ensure a successful cooperation within this context include:

- Industry identifies new fields of applications for industrial robots: basic research is done by academia to gain the required fundamental knowledge
Developments are made in close cooperation to progress from concepts to prototypes: industry defines boundary conditions and provides use-cases for a purposeful development by academia.

Academia and industry jointly push prototypes through TRL\(^1\) cycle: qualifying concepts, systems or tools to commercial products.

The Topic Group “Industrial Robots” (TG-IR) aims to foster the dialogue between industry, academia and applied research through focused input on the field of industrial robots to the Multi-Annual Roadmap (MAR). This input effectively defines and prioritizes the research and innovation topics most relevant to industrial robots.

**Motivation / Challenges Addressed**

Considered to be a “mature” field within the realm of robotics, new developments in industrial robots are strongly driven by the current market situation. Industrial robots are currently important components in large-scale industrial manufacturing, and are used predominately by large-sized companies. The main applications carried out with industrial robots are in production and include a wide range of tasks ranging from welding, painting, to part handling and machine tending.

Although the automotive and metal industries remain the driver for growth of industrial robots in Europe, the strongest growth for industrial robots has been in Asia and in particular China. Industrial robots sales in 2015 grew at a rate of 8% and experienced their third consecutive record-breaking year in absolute terms. Continued growth is expected for the coming years. Further factors and trends that will contribute to the growth of the industrial robotics market include the digitization of factories and manufacturing. In Europe, there is also large potential through increasing use by SMEs, the paradigm shift of mass-production automated lines from productivity to versatility, and the pressure felt by manufacturers due to the ageing workforce. Nonetheless, there is a general consensus among SMEs that industrial robotics itself faces a few hurdles to becoming true mass products, especially concerning ease of deployment and use, interaction and possibly collaboration with humans and/or other machines, and the effort necessary for reprogramming and reconfiguring industrial robotic installations.

Industrial robotics continues to be a highly dynamic field driven by a combination of market pull (often by automotive manufacturing) and technology push (typically through new developments in unrelated domains). The field of Industrial Robotics is highly competitive with many established and mature players. Four of the worldwide ten largest industrial robotics manufacturers are based in the Europe.

The TG-IR aims to address the challenges faced by industrial end-users of all sizes and robot and component manufacturers through a strong technological push from research which is well-synchronized with the present and projected market requirements. The input collected by the members of the Topic Group will serve to update the Multi-Annual Roadmap (MAR) and, on a

\(^1\) TRL = Technology Readiness Level (see [http://www.eu-robotics.net/cms/upload/PDF/Multi-Annual_Roadmap_2020_Call_1_Initial_Release.pdf](http://www.eu-robotics.net/cms/upload/PDF/Multi-Annual_Roadmap_2020_Call_1_Initial_Release.pdf))
longer time-scale, the Strategic Research Agenda (SRA), and as such will help shape the focus of European research, development and innovation (RDI) activities in the field of robotics.

**Scope of Topic Group “Industrial Robots”**
In the following, we will position the TG-IR in relation to the Domains, Technologies, and also to other Topic Groups as described in the SRA and MAR.

**Dependent Market Domains**
High-level market domains (as defined in the SRA) that are relevant for industrial robots include (non-comprehensive, living list):

- **Manufacturing**
  - robot machining (e.g. deburring, grinding, milling, profiling, polishing, marking, …)
  - robot processes (e.g. welding, painting, LASER/water/plasma cutting, cladding, additive manufacturing, …)
  - robot assembly
  - mass production and processing (e.g. automotive, aerospace, food, electronics, pharma, foundry, packaging, …)
  - low-volume and SME production (e.g. material handling, machine supply, assistive robotics, …)
  - large-scale manipulation systems (i.e. aircrafts, ships, constructions)
  - plant and/or machine inspection, monitoring and maintenance
- **Commercial Robots**
  - Inspection and monitoring
- **Civil Robots**
  - Civil infrastructure (e.g. in hazardous and extreme environments, commissioning/decommissioning)
- **Logistics and Transport**
  - Logistics, Warehousing, Loading/Unloading, Palletizing

In general, the domains for industrial robots are currently characterized by the fact that they are operated by trained personnel in a separated work environment. As technologies progress, on the one hand a relaxation on the training requirements may occur, on the other interaction and/or collaboration with human workforce is desired. Nevertheless, it is not foreseen that industrial robots will be used in home/public environments (this may serve as a demarcation to service or consumer robots, e.g. robots for healthcare, diagnostics, entertainment).

**Dependent Technologies**
As stated in the SRA, robots are the result of the integration of a wide range of technologies. Industrial robots exert a technology pull upon and/or will profit from advances in the following technologies:

**Systems Development**
In the field of industrial robots there is a need for new systems engineering technologies. Examples of needs include simulation and engineering tools for offline programming and virtual
commissioning, as well as hardware and software solutions to quickly deploy robotic systems in realistic industrial environments, thus reducing the time and efforts spent by operators in configuring the automation system. Furthermore, there are breaks in the tool chain and missing standards that lead to increased time and difficulties during **systems integration**. Such systems engineering technologies also need to be expanded to the area of **safety** in order to offer safety simulations, safety concept verification, simpler validation and testing possibilities.

**Mechatronics**
Industrial robots will profit from improvements in **mechanical systems, actuators, sensors**, and tools, ranging from flexible, compliant or energy efficient mechanisms, on to lightweight systems and dynamically controlled mechanisms. Such mechanical systems could be optimized for just one application or a very small area of environments. As in the field of systems development, there is a perceived need for standardized interfaces (mechanical, electrical, programming), which could lower engineering costs. Further advances in the field of **communications** and power transmission will also be advantageous for industrial robots (see “**Digitalization of Production**” for further information here).

**Human Machine Interface**
In the context of collaboration and interaction, there is a need for simplification in the areas of **human-machine interface (HMI), interaction, and programming** of industrial robots so that workers are able to operate the robot and automation systems without a great deal of specialized training. Transparent and usable HMIs may significantly reduce the probability of programming or deployment errors. Strategies for programming and teaching cover a broad spectrum, ranging from programming by demonstration, lead-through programming, and task-based teaching, to offline methods such as simulation-based programming. Current research is interdisciplinary, combining robotics with experts from the areas of neuroscience, psychology, and ergonomics to find an appropriate level of complexity for a HMI for a specific task and given a user’s background. Gesture-based sensors (for example Microsoft Kinect and LeapMotion) and contact-based strategies such as tactile sensing and force-torque control are being applied to introduce new interaction modalities beyond traditional computer interfaces and teaching pendants.

**Human Robot Collaboration and Safety**
Due to the demographical change in population as well as for general worker well-being, Human Robot Collaboration (HRC) is an appropriate tool to reduce the physical stresses on the workers and to keep them healthy and productive. Furthermore, HRC offers high value by combining the strengths of humans and robots in the application and by allowing for a flexible level of automation to be implemented, optimally chosen for the production tasks at hand. There is a clear connection between the technologies for **collaboration and interaction** and the TG-IR when considering collaborative robots to support workers of all ages to maintain a strong manufacturing industry in Europe. **Safety** is a non-negotiable prerequisite, but quantification and verification of safety concepts is becoming increasingly demanding, especially in light of the introduction of collaborative robots and their applications. A further focus is therefore on safety standards.

**Perception**
Industrial robots will also profit from advances in **sensing** and **interpretation**. New sensors and methods for interpretation will improve existing applications, open up new ones, increase flexibility, and also contribute to safety during collaboration and interaction. Reliable and cost-effective
sensors can contribute to the robustness and therefore to the economics of many manufacturing applications of industrial robots.

Digitalization of Production – Cyber-Physical Systems (CPS), Industrie 4.0, Internet of Things (IoT), Cloud, Big Data, 5G Networks
With the significant recent and continuing technological advances in the area of sensing, (wireless) communication bandwidth, data storage capacities and computational performance, the realm of industrial production will be significantly affected. Easily available data on all aspects of the value creation chain from manufacturing and assembly all the way up to the ERP level will principally make better production decisions, better business decisions, better service and maintenance approaches, etc. possible. After the present hype around the increasing technological capabilities subsides, it will become clear that the real challenges on this path are the identification of useful data, the proper analysis of these data to obtain actual information i.e. knowledge gain on specific aspects of the industrial production process. As one of the central components of future, extremely flexible production systems (cyber-physical production systems, CPS), industrial robots must act in this augmented digital environment, connecting to its production environment on aspects ranging from production tracking, equipment condition, experience-sharing (e.g. online optimization of robot skills in the “cloud” of manufacturing skills), training of collaborating human workers, optimization possibilities, automatic application programming, etc. The realization of such capabilities will be intimately related to advances in the areas of “Cognition” and “Perception”.

Cognition
Recent advances in machine learning techniques, from autonomous cars to playing games have generated high expectations regarding uses in combination with robotics. Trends in industrial robotics involving flexible, dynamic processes (as opposed to high volume, repetitive tasks), the use of versatile sensor systems (e.g. tactile or vision sensors), and flexible light-weight robots can be difficult to model analytically and are driving efforts to utilize machine learning techniques, either for individual perception tasks, for robot control policies, or for more complicated applications involving a combination of perception, decision-making, and task execution. Currently, the use of machine learning techniques requires large amounts of data for training, and the usage of machine learning results across multiple robot systems therefore implies standardized hardware configurations. While some machine learning applications can make use of data gathered the internet or through existing and readily available sources, more complex applications involving interaction with the real world (manipulation and motion) need to initially generate their own data, which is a time consuming process and a barrier to more widespread usage. Furthermore, risks including possible collisions or safety concerns can further complicate the data generation process. Nevertheless, considerable benefits are expected through directly learning mappings from sensor inputs to robot motions and by that omitting the need to find an analytical representation of the process. Further combinations of machine learning techniques with big data and cloud computing are expected to allow for collective robot learning for robots capable of functioning in a much wider variety of scenarios.

Related Topic Groups
Given the connections described above there is a necessary link to the following other topic groups within the euRobotics aisbl:
Expected Impact on Domains and Products

The following is a non-exhaustive list of expected impacts on domains and products by improvements to technologies as suggested by this topic group:

- To stimulate academic and industrial research and development in the areas identified by evolving market requirements and in the areas opened up by new technology capabilities to make more effective use of public funds and generate added value for European stakeholders.

- To apply industrial robots to new assembly, manufacturing and machining applications, in existing and new domains and markets to stimulate growth in the robotics industry. Examples of new applications in industrial production include tasks with big work pieces, large-scale manipulation, and lightweight material production.

- To apply new concepts from the fields of cognitive robotics, application planning, and control to increased robustness and resilience of production towards uncertainties and to support automatic error recovery and automatic correction capabilities. This leads to improvements in quality and in higher productivity gains and reduced down times.

- To allow for flexible and effective transition between manual and fully-automated production through new methodologies such as scalable degree of automation, and to develop methodologies for choosing the economically best mix of manual work and automated production steps. This also includes transition from 'rigid' specialized high-productivity automation towards smaller-volume automated systems focused on versatility and flexibility.

- To achieve a close-to-reality-simulation model as an engineering platform and database for the overall product and production lifecycle to simplify virtual commissioning and therefore reduce the time-to-market for industrial production solutions.

- To improve system intelligence, usability, and ease of tool chain integration through simulation and engineering tools for offline programming and virtual commissioning. This increases the performance in engineering processes as problems with lost information or dealing with inconsistencies are reduced. This also implies improvements in standardization for improved reusability.

- To improve the mechanics of industrial robots through either new kinematical structures or the development in real industrial environments of promising robot technologies (parallel kinematics robots, cable robots, etc.). These new or enhanced architectures widen the area of robot applications and are one possibility to increase robot sales figures.

- To improve energy efficiency of industrial robots through new use concepts. This is of high importance to handle future challenges concerning limited resources and environmental concerns.

- To allow for easily deployable, reconfigurable, adaptive kinematic topologies and methodologies to choose between the optimal properties for the application at hand.
To improve the integration (lower engineering costs, faster commissioning cycles) of high quality components and devices into optimized production systems. This includes the integration of peripheral devices such as tools, sensors, and feeding and sorting devices.

To improve the flexibility and reusability for other applications/new models/variants. This includes ease of use in re-deployment, configuration, calibration, programming, and tuning, and also encompasses improvements in HMI. This is one significant approach to reduce costs in engineering and automation processes and to bring new production scenarios into operation as fast and efficiently as possible.

To ease the deployment of robotic technologies by supporting, whenever possible, standardization and regulation, as well as fostering public and industrial acceptance.

To support initiatives regarding robotics in education. Motivated and well-informed researchers are necessary for continuous innovations in robotics, and focused and relevant educational efforts are the basis for encouraging new-comers to the field of engineering and for maintaining a sufficient pool of qualified personnel in the future.

Preferred types of EU Projects
From the perspective of the TG-IR, the following types of projects are seen as being the most beneficial to achieving the TG goals:

- Projects focusing on robotic technologies that already left research labs and are being used in some industrial applications, but that may reach deeper and wider applicability by gaining robustness, deployability, reconfigurability, acceptance, and cost reduction. Industrial applications in real scenarios where robots are not yet widespread (automated lines outside the automotive sector, e.g. packaging lines) could be addressed, regardless the size of the industrial partner (not only SMEs). Small consortia are preferred here (3-6 partners). A high TRL can be expected.

- Robotic technologies that are promising and attract much research in academia, but are not accepted by the industry yet. Medium TRL are expected.

- Brand new mechatronic technologies may pave the way for brand new robotic systems. Sensors embedded and distributed in the machine structural parts, wireless communication, wireless power transmission, new motors changing the servo-motor eductor-based paradigm, etc. EU projects should foster creativity and cutting-edge research with dedicated projects. Low TRL expected.

Topic Group Organization and Activity
The primary activity of TG-IR is supporting the SPARC Robotics partnership in the domain of industrial robotics, fostering the directions of robotics in the European Community. The major contribution is expressed into the preparation of EC research work program, through the MAR updating process.

The MAR updating task is coordinated for a Core Team of 5-10 members who are actively involved (at least 1 day per month), and who collate input and compile the information from all members into a readable form. They will be supplied with input and supported by all members, who will be informed at regular intervals about the progress.
The TG-IR is represented by a **Coordinator**, supported by up to two **Deputy Coordinators**. Offices are elected by TG-IR members. The Coordinator is responsible for the direct contact with the Robotics aisbl Board of Directors.

It is expected that **all TG-IR members** actively engage in the MAR updating progress. The Coordinator, Deputy Coordinators and Core Team are committed to transparency, openness, and consensus, and will coordinate all activities (for example establishing a mailing list, setting up necessary infrastructure for collaboration, creating minutes of all meetings in a timely fashion, and setting clear tasks and deadlines).

It is intended for the TG-IR to work in cooperation with existing organizations from the industrial as well as the scientific area (e.g. the MHI Academic Society for Assembly, Handling and Industrial Robotics, etc). These cooperating organizations will be informed about events and discussions within the TG-IR and will show their support through bilateral participation in meetings and events. Organizations throughout Europe that are considered to be valuable partners for the TG-IR will be evaluated and invited to cooperate as well.

**Other important activities** of the Topic Group include:

- Organization and participation in workshops related to industrial robotics
- Publication of white papers with respect to industrial robots and corresponding technologies and abilities
- Members are active in several national and international standardization activities (AutomationML, ISO TC299 “Robots and robotic devices”, …)
- Support the organization of thematic conferences and events: the European Robotics Forum, the conference "Industrial Robotics" in Baden-Baden (takes place every year); the International Symposium on Robotics (ISR) conference at the trade fair "AUTOMATICA" in Munich (every other year). Other events are expected to be included and updated.

**Topic Group Implementation**

Typical instruments used for implementing the TG-IR activities include:

- Telephone conferences with web collaboration support
- In-person meetings
- Offline communications for joint documents on specific items, e.g. iterating a draft of a document, preparing / filling out questionnaires, etc.

The TG-IR will use cooperation with existing professional organizations (e.g. MHI) to establish further channels of communication with industry and research.