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ROBOTICS	FR001
Clean Manufacturing	FR002
High Precision Manufacturing	FR003
Zero Defect Manufacturing	FR004
Maintenance and Support	FR005

Roadmap

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STATE OF THE ART

01 Adaptive and Flexible Systems

- Several research projects are developing adaptive and flexible robotic systems. Scientists are trying to understand how to move from the current approach, in which a robot is programmed for a specific motion (for the goods to be produced), to a new approach in which the robot is "instructed" for a specific task (applicable to different goods). The most promising technologies are autonomous, exchangeable and mobile production units that can change tasks and position on the shop floor (i.e. mobile manipulators, see below).

02 Mobile Manipulators

- The first industrial mobile manipulators have already been sold. However, these are research platforms rather than mature products that can be used reliably in production. One of the major problems of these platforms is the accuracy of the new position, which impacts on the accuracy of the following manufacturing steps. Moreover, the dynamics of a mobile manipulator are very complex and difficult to simulate reliably.

03 Automatic Motion Generation and Task Planning

- A number of software programs that can automatically generate robot motion as a complete 3D model of the environment are already available. However, motion planning under uncertainty and with inputs from moving perception systems is only in its infancy in the most advanced robotics research laboratories.
- Current production chains based on robots exhibit a lack of tools for easy programming in real industrial environments. In particular, there is no commercially available software that can automatically program the robot based on the process to be realized without human intervention. Thus, there is a need for production experts and robotics experts working together to program dexterous operations of the robots. Such programs must be manually rewritten every time production changes.

04 New Hardware for Robotics

- The mechanical design of today's industrial robots reflects the design of the original robots that were first developed in the early 1970s. These, in turn, were based on the basic blocks of even older automation machines. Nowadays, we are seeing new prototypes of industrial robots based on revolutionary mechanical solutions, such as soft robots, compliant robots and electro-pneumatic actuation.
- For service and consumer robots a new generation of sensors is springing up rapidly (e.g. 3D cameras, new touch sensors, new range finder sensors). However, these new sensors are moving into industrial production at a slow pace.

05 Service-based Business Model

- Currently, robot brands catalogue specific robots for specific production tasks. When a customer wants to automate a production task they purchase a robot and pay to integrate it into their production line. In the future, when robots are flexible and can perform more than one task, customers could find it more profitable to pay for a service rather than for the hardware (e.g. you pay for the holes not for the drill).

GAP

Adaptive and Flexible Systems

- Currently, industrial robots have insufficient connections between perception systems and the robot motion system. There is a lack of software systems able to autonomously generate precise motion for industrial robots. Moreover, robots are not capable of resilient behaviors (e.g. detect errors and correct the plan).

Mobile Manipulators

- Self-calibration software tools for mobile robot platforms are missing. Realistic physics simulators for mobile manipulators are missing. Precise perception and 3D modeling of the new production station in which the mobile manipulator is moved to is not available as a commercial product.

Automatic Motion Generation and Task Planning

- Realistic and reliable 3D simulation which takes the robot's physics into account (not only kinematics, but also dynamics and frictions) is missing.
- Industrial-grade motion planning software engines that are able to generate motion paths for different robot's, and motion planning software working with partial knowledge are also missing.
- Software architectures are not sufficiently mature to support high-level task programming.
- Operating systems for robots abstracting from specific hardware are missing.
- Effective and intuitive interfaces for robot programming between robots and humans are missing.
- Close interaction between robots and humans is not intuitive and (in most cases) is not safe.

New Hardware for Robotics

- New actuation concepts and new theoretical models (not based on gears and electrical motors) for describing an actuation are needed.
- Robot mechanics which are intrinsically safe for human interaction are needed.
- New, industrial-grade 3D vision sensors are needed – both in terms of industrial operation range and industrial-grade reliability.
- New sensors for giving robots the sense of touch are needed.

Service-based Business Model

- New business models for robot manufacturers are needed.
- Reconfigurable and flexible robots are needed.
- Companies providing robots on a service basis are needed.

CHALLENGE TO FILL THE GAP

Adaptive and Flexible Systems

- Develop software tools for automatic motion generation which can be programmed at task level instead of at motion level and which can take into account the input from perception systems.
- Develop more intelligent software tools for automatic motion generation that exploit realistic simulators and take into account not only kinematics but also dynamics.
- Develop artificial intelligence tools to monitor the machine/process in more holistic ways (not only with thresholds) for data analytics.

Mobile Manipulators

- Develop more reliable software for 3D sensing and sensor fusion.
- Develop automatic “body-hand-eye calibration” tools, in which the exact pose of the robot platform, the kinematics of the robot arm and the camera parameters can be automatically calculated.
- Improve existing 3D physics robot simulators to reliably simulate the challenging setup of an industrial mobile manipulator.

Automatic Motion Generation and Task Planning

- New algorithms for motion planning under uncertainty or with partial knowledge.
- Improve the reliability of physical properties in 3D robot simulators and develop new algorithms for process definition and planning, taking into account the 3D shape of the item to be produced and the type of process to be performed.
- Set standards for software development at industry level and for software interoperability among the different robot brands.

New Hardware for Robotics

- Develop new actuation prototypes that are not based on gears and electrical motors.
- Improve the reliability and accuracy of 3D cameras to bring the existing ones up to industrial standard.
- Develop new on-board robot sensors that perceive the working space of the robotic-self (e.g. proximity sensors, touch sensors, etc.).

Service-based Business Model

- An algorithm to calculate the return on investment for robots sold on a service basis.
- A study on the economy generated by a new generation of robots.
- Financial support for companies providing robot operations as a service.

RESEARCH PRIORITIES

Adaptive and Flexible Systems

- Realistic 3D simulators and automatic programming tools for task programming in industrial robots.

Mobile Manipulators

- Industrial mobile manipulator hardware and software.

Automatic Motion Generation and Task Planning

- New open-source frameworks for increasing interoperability among hardware and software of different robot brands.
- Automatic programming tools for task programming in industrial robots.

New Hardware for Robotics

- Innovative actuation solutions for industrial robots.
- 3D industry-grade sensors and certifications for new industrial robots.

Service-based Business Model

- New business modes for robots as a service.
- A study on the economy generated by a new generation of robots.

FUTURE TRENDS

Adaptive and Flexible Systems

- The penetration of industrial robots in large factories is almost complete, leaving little space to further automate the production processes. SMEs, on the other hand, are only just beginning to adopt robotics. While robots are excellent at repetitive tasks, it takes a long time to program them for new tasks. Consequently, big companies with long production runs find it profitable to set up and program a robot workcell. SMEs with short production runs cannot afford this investment in time and money. A new generation of robots that can adapt to new production processes and is flexible in processing different products is needed.

Mobile Manipulators

- Current industrial robots are static robot manipulators, which are bolted to the floor. In order to become adaptable to new production runs, robots require greater flexibility so that they can be easily reconfigured according to the changing needs of the production process.

Automatic Motion Generation and Task Planning

- The flexibility and adaptability of industrial robots can be increased only if the robot's motion is automatically generated by the robot controller. Manual motion programming is not only time consuming, but also requires the robot to be taken off-line, putting production on hold.
- Automatic motion generation itself is not enough for complex operations. For example, applications that involve the robot working on the entire surface of a production item, such as quality inspection or machining. In these cases it is not possible to manually define the starting and end points of each motion. Therefore, the robot should be programmed at "task level" or "process level" independent of the item's geometry and position.

New Hardware for Robotics

- Industry requires a new generation of industrial robots to fulfill new applications and overcome new challenges. This calls for new mechanical solutions for building these robots and new sensors to equip them.

Service-based Business Model

- Changing the way robots are used in production and applying robots to new production processes calls for new paradigms in the business model in which robots are sold.

Project Partners

AUTODESK

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NTNU – Trondheim
Norwegian University of
Science and Technology

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