Industrial Robot Automation

INDUSTRIAL ROBOT AUTOMATION

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Abstract - Europe has achieved a leading position in manufacturing and use of robotics, with an annual turnover in robot sales estimated at about €3.5bn, which corresponds to some 33% on a global scale. When taking into account robot automation systems and related services, the annual turnover of some 225 European companies having robotic activities exceeds €13bn and is expanding at current growth rates of 7%.

Today, robotics affects a broad sector of economic activities from automotive and electronics industries to food, recycling, logistics, etc. Up to now however, robot automation technologies have mainly been deployed in capital-intensive large-volume manufacturing, resulting in relatively costly and complex robot systems, which often cannot be used in small and medium sized manufacturing. New branches of robot automation that emerge nowadays such as food, logistics, recycling etc. require radical new designs of robot systems.

Research and development efforts in robotics will strongly contribute to the creation of new opportunities towards European employment and growth. These opportunities are even more pronounced when taking into consideration apparent socio-economic factors such as the overhanging of our society, increasing the productivity of European industries or the need towards a knowledge-based society as formulated in the Lisbon strategy. Robotics is able to address sustainable perspectives to all of these factors.

Keywords – robot, Installations, Automotive Industries

1. INTRODUCTION

In the last 30-40 years, large enterprises in high-volume markets have managed to remain competitive and maintain qualified jobs by increasing their productivity, through, among others, the incremental adoption and use of advanced ICT and robotics technologies. In the 70s, robots have been introduced for the automation of a wide spectrum of tasks such as; assembly of cars, white goods, electronic devices, machining of metal and plastic parts, and handling of work pieces and objects of all kinds. Robotics has thus soon become a synonym for competitive manufacturing and a key contributing technology for strengthening the economic base of Europe.

So far, the automotive and electronics industries and their supply chains are the main users of robot systems and are accounting for more than 60% of the total annual robot sales. Robotic technologies have thus mainly been driven by the needs of these high-volume market industries.

In these global key markets where relatively few robot manufacturers can compete, European robot manufacturers face today a fierce competition.

To remain competitive in the global arena, future manufacturing scenarios throughout all industrial branches will have to combine highest productivity and flexibility with minimal lifecycle-cost of manufacturing equipment. This is particularly valid for today’s small and medium sized productions as these are particularly prone to relocation due to high labor costs.

As mentioned above, so far, robot automation technologies have been developed specifically for capital-intensive large-volume manufacturing, resulting in relatively costly and complex systems, which often cannot be used in small and medium sized manufacturing. Furthermore new branches of robot automation such as food, logistics, recycling etc. require radical new designs of robot systems.

Future robot systems cannot be a mere extrapolation of today’s technology but rather follow new design principles required in a wide range of new application areas (application pull). At the same time, novel technologies, particularly coming from the IT world and the mass markets will have an increasing impact on the design, performance and cost of future industrial robot automation (technology push). From the current trends, it is evident that the operation of robots will increasingly depend on information generated by sensors, worker instructions or CAD product data. Thus it can be expected that manufacturing competence will be further concentrated on robot systems which are expected to become a key component in the digital factory of the future.

In this report, the future of manufacturing automation has been depicted in five scenarios in order to formulate challenging requirements for future robotic systems, identify main obstacles to progress and deduce relevant research directions. The culminating long-term vision (year 2025) in robot automation is that of “A robot assistant serving the worker(s) at the manual workplace and being fully integrated as an agent in symbiotic manufacturing systems”.

Related key technology challenges for pursuing successful long-term industrial robot
automation are introduced at three levels: (1) basic technologies, (2) robot components and (3) systems integration:

1. **Basic technologies**: RTD challenges related to the development of robot assistants concern mainly their required intelligent system behavior and its underlying functionalities like perception, decision making, real-time physical action, system architecture, learning, and use of natural language and dialogues.

2. **Robot components**: Industrial robots have always been depending on the availability of key-components such as actuators, sensors, materials and human-computer-interfaces as enablers for novel systems and applications. Besides component functionality and performance, aspects of mechanical, electrical and informational integration within standard system architectures are of increasing importance. Microsystems have entered as sensors, actuators and switches robotics. Further potential lies in creating robot structures which embed micro-systems (sensors, actuators, circuits) into materials (so-called smart matter systems) helping to create new light-weight, low inertia material for new actuation devices.

3. **On a systems integration level**, the main challenges lie in the development of methods and tools for instructing and synchronizing the operation of a group of cooperative robots at the shop-floor.

Furthermore, the development of the concept of hyper flexible manufacturing systems implies soon the availability of: consistent middleware for automation modules to seamlessly connect robots, peripheral devices and industrial IT systems without reprogramming everything (“plug-and-play”); the introduction of wireless techniques on the shop-floor; mobile work-cells involving mobile robots and manufacturing equipment for a swift change-over of manufacturing lines to new production needs; and, the establishment of a life-cycle-oriented approach of production equipment (procurement, financing, planning).

Competitive manufacturing of the future will increasingly depend on the progress of robotics technologies and the availability of safe and cost-effective robotic products and related services.

We expect significant socio-economic impact in the following four categories of industrial stakeholders: end-user industries, existing robot automation manufacturers and system integrators, new start-ups in robotics and product-related service-industries.

### 2. CURRENT SITUATION OF ROBOT AUTOMATION IN EUROPE

Today, Europe has achieved a leading position in manufacturing and use of robotics equipment. The annual sales volume of robots is estimated at about €3.1 billion, which corresponds to some 33% on a global scale, see Figure 1.

When taking into account sales of robot components, system integration and other services, the total revenues add up to some €13 billion.

Robots are special in that they both enable flexible knowledge-based production and are a complex knowledge-based product by themselves. The relatively few European robot industries and component manufacturers have a pivotal role in the manufacturing supply chain, but they are directly exposed to stiff competition, particularly from Japan and Korea.

A comparison of robotic usage is indicated by the robot density, i.e., the number of robots per 10,000 workers, see Figures 2. Despite the differing
character and structure of national industries, from this robot density number it can be seen that European robot density lags behind Japan. Another factor is the dominant number of robots being used in non-automotive applications with respect to automotive sector which is obvious for Finland and Sweden.

![Image](image_url)

*Figure 2: Robot density in automotive*

However international efforts are just as pronounced:
- The Japanese Robot Association (JARA) has launched robotics initiatives worth €300m;
- Korean research and industry is in the progress of a strategic robotics research programme worth €400m.

Both programmes are embedded into large national roadmaps towards gaining competitive edges in a critical key technology for future manufacturing across all industries.

### 3. CURRENT AND FUTURE KEY-BUSINESS DRIVERS

So far, industrial robot technology and products have largely been driven by the requirements of the automotive and the electronics (light assembly) industry. It is foreseen that future manufacturing paradigms in these industries will still be largely depending on future robotic products, solutions and services. However, the emergence of other applications from non-automotive industries opens up new technological horizons and market opportunities for robotic technologies.

#### 3.1 Automotive Industries

So far, robots have been mainly used in the automotive industries, including their supply chains, accounting for more than 60% of total robot sales. Typically prime targets for robot automation in car manufacturing are welding, assembly of body, motor and gear-box, and painting and coating. Automotive industries as the key application driver in terms of cost, technology and services robotics industry are subject to fierce global competition (see Figure 3).

![Image](image_url)

*Figure 3: Origin of robot supplier in the automotive industry*

Furthermore robot systems increasingly become the central portion of investments in
automotive manufacturing which may reach 60% of the total manufacturing equipment investment in the year 2010 (for car and 1st tier suppliers). Generally it is estimated that the cost of a robot automation investment in these industries accounts to 4 times the unit prize of a robot.

The degree of automation in the automotive industries is expected to increase in the future as robots will push the limits towards flexibility regarding faster change-over-times of different product types (through rapid programming generation schemes), capabilities to deal with tolerances (through an extensive use of sensors) and costs (by reducing customized work-cell installations and reuse of manufacturing equipment). These immediate challenges lead to the following current RTD trends in robotics:

• Expensive single-purpose transport and fixing equipment is replaced by standard robots thus allowing continuous production flows. Remaining fixtures may be adjusted by the robot itself.

• Cooperative robots in a work-cell coordinate handling, fixing and process tasks so that robots may be easily adjusted to varying work piece geometries, process parameters and task sequences. Short change-over times are reached by automated program generation which takes into account necessary synchronization, collision avoidance and robot-to-robot calibration.

• Measuring devices mounted on robots and increased use of sensor systems and RFID-tagged parts carrying individual information contributes to better dealing with tolerances in automated processes.

• Human-robot-cooperation bridges the gap between fully manual and fully automated task execution. People and robots will share sensing, cognitive and physical capabilities.

3.2 Electronics Industries

Electronics industries have reached most important advances in the use of robot automation planning and operation responding to highest requirements in flexibility (uncertain product lifetimes and variants, throughput, lot sizes) and cost by:

• Consistent modularization of equipment and control in order to adapt to varying degrees of automation, to allow the reuse of equipment, and to add capacity on demand (extension of manufacturing work-cells);

• Lean and structured manufacturing layouts to minimize transport and to effectively combine manual and automated work-cells;

• IT-based engineering tools for concurrent product/production planning and design, programming and servicing of the equipment;

• Automated testing of electronic components (computer vision, electronic test equipments) for a 100% quality control;

• Advanced manufacturing processes (joining, wiring, coating, gluing) which are at the same time suitable for mass products and robot guidance and control. Here, laser based processes will play an increasing role in terms of joining, coating, cutting, and finishing.

3.3 Current and Future Industries Acting as Application Drivers

There are numerous new fields of applications in which robot technology is not widespread today due to its lack of flexibility and high costs involved when dealing with varying lot sizes and variable product geometries. New robotic applications will soon emerge from new industries and from SME’s, which cannot use today’s inflexible robot technology or which still require a lot of manual operations under strenuous, unhealthy and hazardous conditions.

Relieving people from bad working conditions (e.g., operation of hazardous machines, handling poisonous or heavy material, working in dangerous or unpleasant environments) leads to many new opportunities for applying robotics technology. Examples of bad working conditions can be found in foundries or the metal working industry. Besides the need of handling objects at very high temperatures, work under unhealthy conditions takes place in manual fettling operations, which contribute to about 40% of the total production cost in a foundry. Manual fettling means heavy lifts, strong vibrations, metal dust and high noise levels, resulting in annual hospitalization costs of more than €150m in Europe. Bad working conditions can also be found in slaughterhouses, fisheries and cold stores where beside low temperatures also the handling of sharp tools makes...
the work unhealthy and hazardous. Other examples where robots can improve the working environment are painter workshops, glazier workshops and garbage handling plants.

4. A EUROPEAN VISION FOR LONG-TERM INDUSTRIAL ROBOT APPLICATIONS

Long-term visions toward industrial robots of the future have been depicted in five scenarios which are given in the following as examples:

A. Robot assistants as a versatile tool at the workplace;
B. Robot assistants in crafts;
C. Robots for empowering humans;
D. Multi-robot cooperation;
E. Hyper-modular Work-cell Designs.

A long-range vision (15 years) has been formulated towards the development and use of industrial robotics in manufacturing scenarios of the future.

A robot assistant serves the worker(s) at the manual workplace and is fully integrated as an agent in symbiotic manufacturing systems.

The robot assistant should have the following features:

- Displaceable (with very little effort) or mobile (possibly with autonomous navigation capability);
- Its arm is inherently safe so that its impacts are harmless;
- Capable of understanding human-like instructions (in end-user terms);
- Coordination with other robot assistants to perform larger cooperative tasks;
- Have access to CAD or digital factory data bases for generating programs and for parameterizing manufacturing processes;
- Possesses sensing capabilities to identify and locate objects and to control forces and torques;
- Deployable in existing manufacturing environments through plug and play functionality;
- Be able to learn skills and optimize them during process execution.

5. MAIN OBSTACLES TO PROGRESS

The realization of the described long-term vision is subject to overcoming the following barriers:

- Man-machine-interaction: Today, manufacturing tasks cannot be expressed in intuitive end-user terms as would be typically required for instructions by voice. Multimodal dialogues based on voice, graphics, and texts should be initiated to quickly resolve insufficient or ambiguous information;
- Mechanical limitations: Still, robot mechanics account for some 80% of the system price.

For some components, particularly gears, there exists a painful dependency on Japanese suppliers. In order to decrease this dependency, new drive lines should be developed where high density motors and compliant compact gears (e.g. on the basis of mechanical wave generators) with integrated torque and position sensors are used. Advanced control of such sensor based drive systems will make it possible to decrease weight and cost without reducing the robot performance. Furthermore a cooperative space-sharing robot (“no fences”) requires harmless motions. This can be achieved by intrinsically safe designs or suitable sensor equipment.

- Sensors: A dependable, full 3D recognition is required for work piece and worker localization in less structured environments (e.g. a craftsman’s shop). Inexpensive sensors do not exist yet but high volume entertainment and supervision applications will make this technology affordable;
- Robot automation life-cycle costs. Especially for investments into cooperating (assistive) robots productivity gains are probably less pronounced than quality gains, which in some cases will result in severe cost limits of such systems to achieve cost-effectiveness;
- Socio-economic factors. Especially in areas with little or no automation a strong conservative attitude in industry towards advanced mechatronic systems may slow down investments in novel robot systems. The introduction of robotics into industries characterized by bad working conditions and low status can contribute to changing their attractiveness to employ young people;
- Standards. First standards towards cooperative
robots and intelligent assist devices (e.g. “smart balancers”) are about to emerge. New standards for robot assistants allowing physical interaction at normal working speeds will be required. Setting new standards needs committed industries to support the high cost and time involved.

6. KEY TECHNOLOGY CHALLENGES TO PROGRESS

Key technology challenges for pursuing successful long-term industrial robot automation are introduced on three levels: basic technologies, robot components and systems.

6.1 Basic Technologies

RTD challenges related to the development of robot assistants concern the required intelligent system behavior. Underlying relevant functionalities to address are perception, decision making, real time physical action, system architecture, learning, use of natural language and dialogues.

• Perception. All major functions of a robot assistant are based on “a priori” knowledge about its environment, work pieces and skills (perception, manipulation, and interaction). Therefore knowledge has to be acquired through interaction with the environment, with people or possibly through databases or other repositories (e.g. the www). For this, appropriate models and ontology of the environment, task and interaction spaces have to be found and adequate representations of world model data and skills have to be formulated.

• Decision making. Today task generation is performed offline by geometric or even symbolic planners on the basis of consistent a priori world knowledge. Future aspects will require on-line task generation based on stochastic information thus leading to higher degrees of reactivity and interaction.

• Real time physical action. Especially in the presence of people, physical actions by the robot have to be perceived as goal-driven, socially acceptable and expressive. In this context, aspects of ergonomics and behavioral psychology need to be adopted to arrive at methods for motion planning and generation.

• System architectures. Future robot assistants require the implementation of learning mechanisms which impose additional requirements on the robot’s system architecture. Furthermore aspects contributing to the system’s dependability such as advanced abilities to cope with disturbances, exceptions or failures (“graceful degradation”) require adequate system architectures.

• Learning. A robot assistant should continuously improve its capabilities by acquiring new knowledge and skills. Besides the necessary functions for sensing, moving and acting, such a robot should exhibit cognitive abilities enabling it to focus its attention, to understand the spatial and dynamic structure of its environment, to interact with it, and to communicate with other agents and with humans at the appropriate level of abstraction.

• Language and dialogues. Human-robot interaction will have to be based on multi-modal communication with natural language as the most versatile and intuitive means of instruction. Dialogues should help extract the user intent or interactively resolve ambiguous situations and should be perceived as intuitive, efficient and goal driven. For robustness and performance, domain-specific (welding, handling, machining …) syntax and data is needed.

Therefore methods have to be sought which control and permit dialogues depending on situation, environment and machine state.

6.2 Robot Components

Industrial robots have always depended on the availability of typical key-components such as actuators, sensors, materials and human-computer-interfaces. Besides component functionality and performance data, aspects of physical and logical integration within standard system architectures in hardware and software are of increasing importance. It should be noted here that there is a clear trend to share both components and architectural aspects at least in parts with other complex mechatronic systems such as service robots or even automobiles (“convergence of technologies”).

• Actuators: Today electro-magnetic servo-drives are the governing actuator for robots. However with the advent of assistive robots electro-hydraulic motors may come into play. Even though robot gears are considered mature components with few open
research questions they represent a major bottleneck towards high-precision, light-weight and low-cost robot arms. Research should aim at alternative gear designs both for servo drives as well as for novel actuator principles to be taken up by European manufacturers. New sensor types such as magnetostrictive torque sensors and capacitive low-cost high precision encoders can provide critical benefits to the drives in terms of hybrid force/torque control.

- Sensors: So far, current sensor systems have not displayed enough robustness and accuracy at appropriate costs to be widely utilized in both industrial and everyday environments. A major breakthrough towards flexibility and robustness would emerge from the commercial availability of low-cost 3D sensors (at some €100). Furthermore embedding sensors in robot structures as tactile and non-tactile sensing (e.g. artificial skins) will be necessary for robots in human sharing environments. The tool is a most important interface by itself which the worker can use to intuitively calibrate and program the robot relative its environment and work object. However, this requires as 6 degrees of freedom force/torque sensor to be mounted between tool and robot flange. These sensors are very expensive today and an important task is to develop a new concept for low cost and moderate accuracy 6 DOF force sensing.

- Materials. Currently novel materials which embed actuation and sensing properties are under research (“adaptronics”), particularly in the aerospace and automotive field. A significant potential lies in creating robot structures which follow these new principles: To “grow” structures instead of removing material for manufacturing robots, to embed micro-systems (sensors, actuators, circuits) into materials and to create new light-weight, low inertia material for new robot arms.

- Robot Arms: Today, the weight/payload ratio for robot manipulators is typically of the order of 10 to 50, mainly due to heavy drives which account for some 60% of the arm weight. Large masses result in a significant inertia, which makes it difficult to increase speed and at the same time such systems are not well suited for operation in the presence of humans. Thus the need for new designs of systems with a low weight to payload ratio and possible intrinsic safety arises. This requires an entire new approach to design and the use of new types of advanced materials and new actuators. Optimized weight to payload ratio will generally be more efficient and in some cases the added mechanical flexibility is desirable (e.g. to allow operation in cooperation with people). Such mechanically flexible robots can only have repeatability and performance similar to existing robots through use of sensory feedback in combination with new methods for control.

- Intuitive human-robot interfaces should support an efficient transfer of knowledge and skills between user and machine. While multi-modal interfaces will be very much driven and thus provided by the IT industries, typical interfaces for robot instruction will have to be developed within the robotics community, such as robust gesture recognition, haptic displays.

- Microsystems and mechatronics. Microsystems typically embed transducers, actuators and circuits on millimeter scale and are make up valves, optical or mechanical sensor-systems, miniature servo-drives and micro-switches. Currently novel materials which embed actuation and sensing properties are under research, particularly in the aerospace and automotive field.

A significant potential lies in creating robot structures which embed micro-systems (sensors, actuators, circuits) into materials (so called smart matter systems) helping to create new lightweight, low inertia material for new actuation devices.

### 6.3 System Integration

The main R&D challenges of future industrial robot systems are as follows:

- Fine manipulation/high precision. Installation and change-over times of robot work-cells are highly dependent on negotiating tolerances in processes, product geometries and product position/presentation. This aspect is even more emphasized as product components decrease in size (micro, nano...). A goal is to account for required precision on the basis of existing (non-precision) machines by use of increased numbers of sensors and improved sensor data processing.

- Human-robot-collaborative work-cells. A cooperative task execution between robot and worker can increase the overall productivity through a perfect split of capabilities (“worker is better at/robot is better at”). This idea also extends to the vision of making robots a commodity in manufacturing and crafts.
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• Cooperating robots. As unit prices drop at increasing rates, the cost of typical robot peripherals (conveyors, feeders, positioning devices, fixtures ...) can be drastically reduced and at the same time provide more flexibility. The result would be a network of interlinked robots which cooperatively transport, machine, handle and assemble workpieces. A typical, simple scenario is a robot presenting a work-piece and positioning it so that a second robot can work on that piece. RTD tasks especially comprise scalable/distributed architectures for multiple robots, so that synchronization, sensor data processing, programming, task allocation, decision making and diagnosis can be organized and managed in a distributed system.

• Hyper flexible manufacturing systems. Product volumes and life-times are especially uncertain for consumer goods (electrical appliances, mobile communication, articles of infotainment). An immediate change-over may give additional opportunities to react to market developments and receptivity. The adaptation to new batches, product variants or new products should be shortened by typically one order of magnitude compared to today. This should result in a consistent modularization of manufacturing systems both in terms of software (components, interfaces) and hardware (interfaces, signal, energy transmission):

  o A consistent middleware of automation modules to connect robots, peripheral devices and industrial IT systems (in a mechanical, electrical and especially logical way) without reprogramming (“Plug and Play”)

  o The “wireless shop floor”. Signal transmission should be detached from wiring and switching cabinets. Closely associated to this challenge are aspects of data security.

  o Mobile work-cells should facilitate the change-over of manufacturing lines to new compositions or, in a more advanced way to “abandon” the robot work-cell in favor of installing robots temporarily at the workplace/workbench.

  o Establishment of a life-cycle oriented consideration of production equipment (procurement, financing, planning)

• Micro-and nano-manufacturing. As products differ from traditional products and manufacturing, the development of low-cost, dependable micro manufacturing equipment constitutes a major challenge. These systems generally incorporate rich sensor capabilities for optimized process control, robotic devices for automated handling, assembly and machining of micro-parts. It is expected that the manufacturing of nano-systems will follow radically new and fully automated processes (from solid state physics, generative processes from biology) requiring new robotics devices, possible based on completely different motion generating principles (controlled electrical, magnetic fields, atomic forces ...).

7. EUROPE’S COMPETITIVE POSITION IN INDUSTRIAL AUTOMATION

From the broad sector of economic activities which are affected by robotics, it is obvious that research and development in this field will contribute to creating new opportunities towards European employment and growth. These opportunities are even more pronounced when taking into consideration apparent socio-economic factors such as the over-aging of our society, the need for increasing the productivity and competitiveness of European manufacturing industries or the need towards a knowledge-based society as formulated in the Lisbon strategy. With regard to the major societal challenges identified in the Kok report (i.e., the graying Europe, the EC enlargement, economic growth, productivity and employment), the role of robotic can be summarized as follows:

• The graying Europe: Over the next two decades the industrialized world is going to experience a significant growth in the number of people above 65 so that the dependency ratio is going to grow from about 22% to more than 45% in almost all EU countries. Contrary to this trend the employment rate is even declining for physically demanding jobs.

Employment aspects require elderly workers to remain in their jobs which calls for machines, tools or especially robot assistants to enable the worker make use of their skills and experience without the full physical strain.

• Growth, productivity and employment: The European growth gap to the US and Asia has
widen which can be attributed to a lower investment per employee and to a slow-down of the technical progress in the mid-1990s. Increasingly newly created jobs tend to be low-wage jobs, which is in contrast to required investments in R&D, training and education. Also it is remarked that Europe’s industrial structure is based on more low- and medium-tech industries. Manufacturing employment continues to be on the decline, currently representing about 18% of employment in Europe. Manufacturing and application of novel robot systems strongly contributes to shift resource-intensive industrial activities to a knowledge-based economy. This has a positive effect on employee skills and on job satisfaction. As robotic automation in Japan is seen as a strategically important enabling technology, and consequently is strongly supported by the Japanese government, it is important to realize here that a lead of Japanese suppliers of robot automation will be detrimental to the still healthy European robot industry.

- EC enlargement: Current and future enlargement of the EC will, besides an increase in population, add significant, mostly low-cost, manufacturing capacities. The transformation process from a low-cost to a knowledge and skill-driven manufacturing is critical as it implies significant investments in manufacturing equipment, new processes, high-added value products and trained personnel. New robot technologies may play a key role in transforming these industries and protecting them against increasing competition from low-wage countries.

- Standardization is particularly important for complex systems such as robotics to reduce manufacturing costs of the robot units themselves, to ensure exchangeability between components from different manufacturers and to reduce dependence on specialized robot experts. These factors affect, among others, training efforts for personnel from robot manufacturers, system integrators and end users. From a European point of view, standardization will also help to further improve the competitive position of the European robot industry vis-à-vis Japan in particular. Lack of standardization will shatter European resources and will make it easier for non-European robot manufacturers to penetrate the European market.

8. BUSINESS CASES

A broad manufacturing base is vital for Europe as it spurs demand for everything from raw materials to intermediate components, from software, financial, health, accounting, and transportation services in the course of doing business. Industrial robotics will increasingly gain importance as a cornerstone technology in future manufacturing scenarios. The automotive sector provides a good example. The production of automobiles stimulates the demand for everything from raw materials (in the form of coal and iron) to manufactured goods (in the form of robots) and to the purchase of services (in the form health insurance for the companies’ employees).

Competitive manufacturing of the future will increasingly depend on the progress of robotic technologies and the availability of robotic products and related services. We expect significant business and socio-economic impact in four categories of industrial stakeholder: end-user industries, existing robot automation manufacturers and system integrators, new start-ups in robotics and product-related service industries. The objective regarding end-user industries is to maintain competitiveness and create high quality jobs. Even in relatively slow economies the manufacturing industries are having difficulty finding skilled workers as was revealed in recent US-based studies. Innovations as highlighted in this report can contribute to this transformation through:

- Seamless robot automation concepts: from manual workplaces with robot assistants to automated systems capable of managing manufacturing uncertainties;

- Automated robot configuration and radically new programming through intuitive instruction and skill-based task specification;

- Life-cycle oriented reusable robotic and work-cell components that can be configured with a minimal set-up time;

- Increasing robot penetration in manufacturing: today, only 15% of possible robot automation potential is being exploited; further exploitation improvement will very likely contribute to less unemployment as more manufacturing capacity will remain in Europe. This particularly relates to industries which have only used little automation;

- Interactive industrial robots free the workforce from physical work. Therefore, equal opportunities
on the shop floor in terms of gender and age could be promoted;

• Less physically demanding jobs in manufacturing through assistive robot systems.

Concerning existing robot manufacturers and system integrators, robots will remain a growth market for the next years to come, as manufacturing will depend on further productivity gains both in the automotive and particularly in the non-automotive industries. The creation of novel products, solutions and services in non-automotive sectors is vital for robot manufacturers and system integrators, since it will permit them to break with potentially dangerous dependencies they now have on robotic technologies tailored only for automotive applications. Technological advances may open-up important benefits and options for both robot manufacturers and system integrators:

• Increasing productivity in labor-intensive industries through a scalable robot automation approach, thus providing competitive solutions for new manufacturing paradigms, new products and innovative business models;

• Penetration in flexible small-scale manufacturing and in crafts, especially by introducing new assistive robots.

• Some new and very specific robotic products, especially cooperative robots, which address the needs of specific applications, may be outside the product portfolios of existing robot manufacturers. Such new technologies may be offered by innovative spin-offs;

• Life-cycle-oriented approaches in the planning, implementation and operation of robot systems offer chances for new services and businesses in a growing market.

9. REFERENCES


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