Innovation Outlook for Industrial Robotics

Alexander CZINKI, Hartmut BRUHM

Abstract: Based on publications of major robotic organizations and individual assessments of the authors, the paper focuses on the innovation necessities and perspectives of robotics nowadays. It also treats the main innovation drivers as well as the classification and explanation of the major fields of innovations in robotics. This can serve as a helpful tool for the identification of relevant research and development areas in the future and can also help component and system suppliers to get a clearer picture of future robot systems.

Keywords: industrial robotics, innovation in robotics, innovation drivers in robotics, applications of robotics, future trends in robotics

1 Introduction

Robotics has – with regard to its first serious application in industrial environments in the early 70's of the last century – no longer the typical characteristics of an emerging technology. In fact, robots have become standard equipment in modern manufacturing sites, providing fast and reliable routine operations. The technology required for standard tasks such as pick-and-place operations and the like has been well known for decades and is – more or less – available to all robot manufacturers alike.

Hence, the classical robot manufacturers are facing an increasing number of competitors in the market, forcing them to set themselves apart by addressing new markets and by applying new technologies.

Obviously, innovation will play a key role in the attempt of robotics industry to gain an advantageous position in an increasingly globalized market.

Prof. Dr.-Ing. Alexander Czinki, Prof. Dr.-Ing. Hartmut Bruhm, both University of Applied Sciences Aschaffenburg, Germany

Major innovation drivers are represented by the increasingly diverse application scenarios covered by modern robotics. The enlarged scope of applications provide niches for specialized companies and also growth potential for the major market players.

The objective of the following article [see also:[10]] is twofold: Firstly, it will focus on key innovation drivers in robotics. Secondly, it will present a classification and explanation of the major fields of innovations from the author's point of view.

2 Key Innovation Drivers

As stated before, a retrospective view on robotics covering the last few years reveals substantial changes in terms of market and technology drivers. Recently, manifold trends have changed the shape, the performance and the fields of application of modern robotic systems. Prior to an investigation of these current fields of innovations, it seems advisable to illuminate the main driving forces behind these trends – the innovation drivers. Subsequently, a set of innovation drivers is introduced, which will – from the author's point of view – significantly influence the developments of robotics in the near and midterm future.

2.1 Fast Performance Growth

Although industrial robots have reached a high degree of maturity by now, robotics systems nevertheless achieve a steadily increasing level of overall performance. This is partly due to improvements of robot systems themselves, but additionally it is also strongly driven by improvements of peripheral devices and equipment such as improved gripper systems, tooling, and the like.

While in the past, robotic companies had to develop most of their hardware by themselves, they will more and more benefit from developments driven by other high-tech areas such as mobile communication, game consoles and the like in the future. Even though an adaptation of these components will often be necessary before they are applicable to industrial robot systems, the overall costs for implementing new technologies into robot systems will be in many cases considerably reduced compared to pure in-house developments as they were standard in the past.

2.2 Applications: Classical Fields Alter, New Fields Emerge

Many of the classical application fields for industrial robots are rapidly changing. For example, the automotive industry – still being the biggest customer of industrial robots – will soon be facing a transition from classical combustion engine driven vehicles towards vehicles that implement – in one way or the other – electrical drives. As a result, robot systems will have to adapt to these new applications, by contributing to a higher automation level in the production lines for electrical drives, batteries, transformers and the like.

Besides changes in classical fields of application, numerous new application areas have recently been emerging. The automation of solar cell production, the increasing number of wind energy plants and the production of large carbon fiber structures for automotive and aeronautical applications provide promising perspectives for the robotics industry already in the near future.

2.3 Enhanced Product Diversity combined with Reduced Product Life Cycles

Many traditional markets are mature and not few of them are even faltering nowadays. Many companies respond to this situation by an increasingly diverse product portfolio. While this is reasonable from a strategic standpoint, it generally puts significant strain on production processes due to the reduced lot sizes and an increased number of product variants that usually come along with product diversifications.

With new technologies emerging in an ever decreasing time, product life cycles (PLC) are becoming extremely short and there is no serious evidence that this development will stop or reverse anytime soon.

Both, the increasing product diversity and the reduced product life cycles will – in the long run – challenge robot manufacturers and automation companies alike and will force them to develop systems with a significantly higher flexibility than we experience today.

2.4 Altering Global Market

In the course of a global market shift, the robotics and automation industry has not only the opportunity to address new fields of application but it also has the chance to enter new regions of the global market. Increasing incomes in many of the formerly low wage countries place an increasing automation pressure to these countries and therefore open new sales opportunities for the robotics and automation industry.

Additionally, robots will more and more be applied not only for the sake of labour cost savings but also in order to meet the high quality demands of modern production.

All these considerations suggest, that sales of robot systems to newly industrialized countries as well as to less developed countries will continue to grow.

3 Major Fields of Innovation

The key innovation drivers described in the previous chapter manifest themselves in specific innovation trends. Some major trends in industrial robotics are described subsequently.

3.1 Increased Adaptability of Robot Cells and Robot Periphery

Reduced lot sizes and an increasing number of product variants will force manufacturers to adapt their production equipment to new products more frequently in the future. While robot systems themselves can – due to their free programmability – be easily adapted to new tasks, complete robot cells with their peripheral equipment usually only have limited flexibility.

Figure 1 illustrates a concept for a highly flexible robot cell, which avoids many of the flexibility flaws of classical robot cells. The flexible robot cell concept was developed and patented by the University of Applied Sciences, Aschaffenburg.

Instead of having the peripheral equipment individually adapted to a specific product range and being permanently fixed within the robot cell, the flexible robot cell concept integrates the robot periphery into task-specific modules (e.g. welding modules, grinding modules, measuring modules, …). These modules have a detachable mechanical connection to the cell floor. Furthermore all electrical, network and fluidic connections of a module are combined in a single, standardized connector. If a production change requires a reconfiguration of the robot cell, modules can easily be detached and removed from the robot cell. New modules can be configured and tested outside the robot cell. The installation of a pre-configured module in the robot cell takes only a few minutes, thus reducing production down-time to almost zero. The locking of the modules within the cell is achieved by a centralized, pneumatically-driven locking mechanism. The connectors which are used to link the modules with the cell are electrically coded. By this means the overall system controller permanently has all relevant information about the cell such as the type of modules inserted, the number of modules loaded in the cell and their location within the cell grid.

The modularized cell concept offers some significant advantages, such as:

- easy setup
- easy reconfiguration
- ultra-fast adaption to new products(reduced change-over time)
- minimal downtimes for maintenance
- standardization of components
- easy upgrade for cells

The concept described here is an example for the innovations necessary

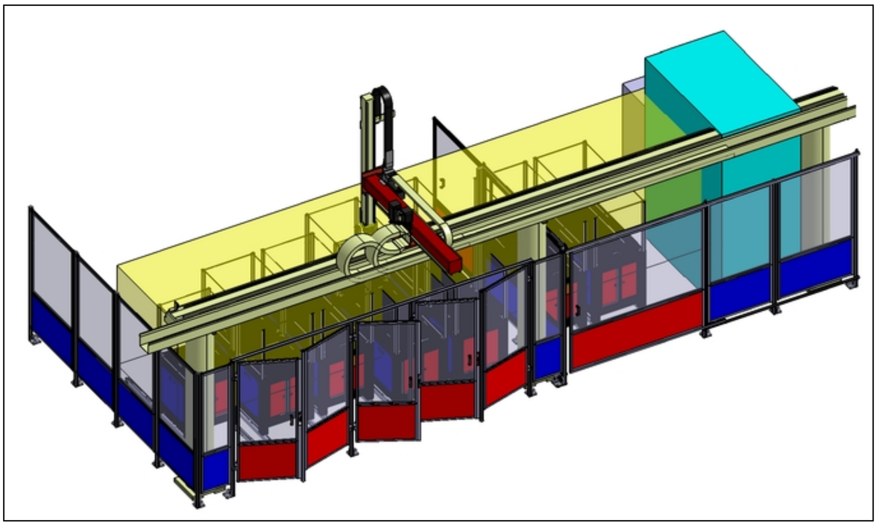

Figure 1. *Modularized Robot Cell [Univ. Applied Sciences Aschaffenburg]*

to master a transition from robot-based mass volume production to robot-based low volume production.

3.2 Vanishing Boarders between Simulation and Reality

While robot simulation itself is everything but new, the extent to which simulation tools are used within robotics is rapidly growing.

While in the past many robot simulations were limited to simple representations and visualisations of robots, future systems will provide a considerably higher functionality. As simulation and robot control systems will more and more merge, powerful features will become available, such as: real time dynamic simulations covering the robot and its entire working environment, ex ante singularity warnings, real time path and workspace surveillance and the like. Even an inclusion of flexible body simulations of the robot's structure into path planning algorithms is conceivable. It is obvious that these new capabilities will make robot systems safer, more reliable and more efficient in the future.

3.3 Smart Robot Controllers

The increasing computing power of modern robot controllers will allow them to assimilate control tasks that are nowadays still generated off-line or in separate controllers.

Figure 3 illustrates an example for such a task integration which was achieved in the framework of the LARISSA research project [6]. The project consortium – consisting of the robot manufacturer Reis Robotics, a manufacturer of laser deflection systems (Raylase) and the University of Applied Sciences Aschaffenburg – developed concepts for the integration of the formerly separate control of the laser deflection unit into the main controller of a robot system. As a result, the separate controller became obsolete, saving significant system costs. Furthermore, the integrated control of the robot arm and the laser deflection unit allowed for a significantly better coordination of the robot and deflection mirror movements, increasing the performance of the overall system – in a typical application – by the factor of five [6].

However, robot controllers are not only likely to become more powerful

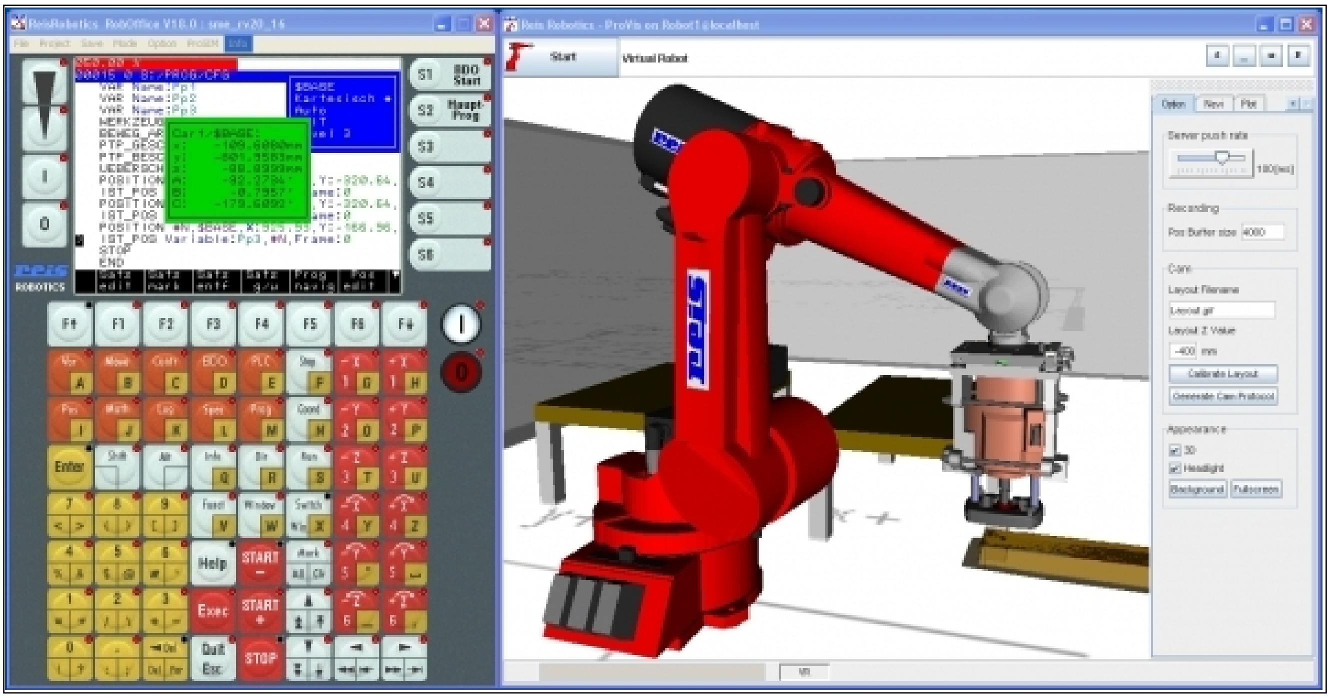

Figure 2. *ProVis Simulation environment [Reis Robotics]*

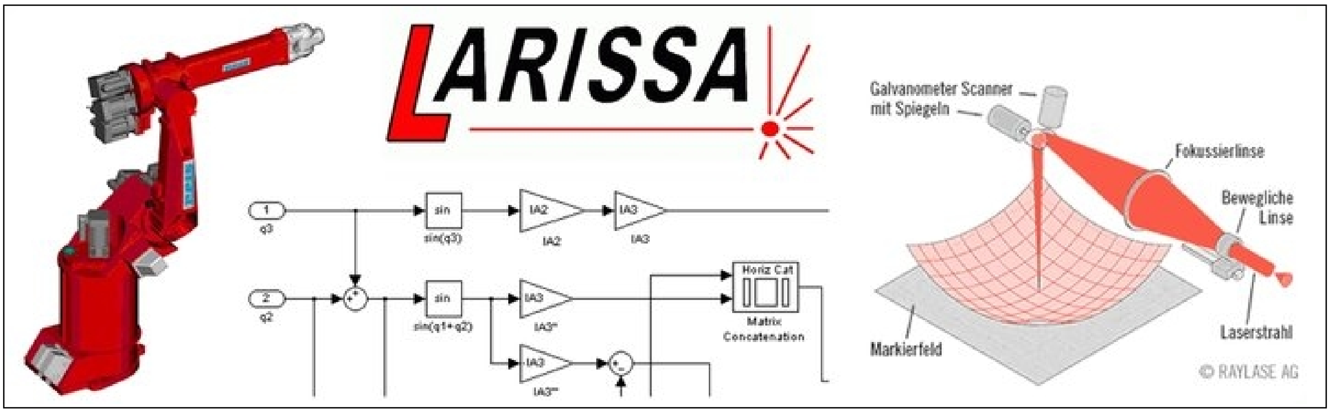

Figure 3. *LARISSA-Project: Robot, Algorithms and the Laser Deflection Unit [Univ. Applied Sciences Aschaffenburg, Reis Robotics, Raylase]*

in the future. They will also become more user-friendly and smarter in the way how they handle standard and exceptional situations. Based on the increased computational power, robot controllers will include more self-calibrating and self-tuning capabilities, allowing them to adapt to changes in their setup, work load and the like. Also fault detection and fault tolerance of future systems will be significantly higher compared to current systems.

Finally, it is likely that the trend towards the integration of more powerful and versatile communication protocols and interfaces will continue. This will include new and open standards, many of them allowing future systems to link themselves with a multitude of different components from varying suppliers in a "plug and produce" fashion.

Besides classical bus interfaces, future systems will presumably support open and non-industry communication standards (such as: GSM/UMTS/WLAN/...) allowing remote operation and diagnosis via local or telematics interfaces [7].

3.4 Advanced HMI

Human machine interfaces have recently changed rapidly. Although this development is mainly driven by consumer products such as mobile communication, game stations and tablet computers, it is more than likely that these new technologies will be introduced to industrial automation and robot applications as well. As a consequence, future robot interfaces will allow intuitive interaction via touch, speech or gestural information. In the long run also elements from augmented reality will find their way from research laboratories into industrial robotic devices.

3.5 Redundant Kinematics and Cooperative Robots

In many industrial applications the capabilities of standard robots are extended by the use of one or more additional axes. As a result, many of these robots have a set of redundant axes. While in the past this has often only be used in order to provide a variable offset to the workspace of the robot, presently the specific characteristics of redundant robot kinematics are moving more into the focus of robot developers and robot users alike. Redundant axes (redundant degrees-of-freedom, respectively) allow a reconfiguration of the robot poses without change of the position and orientation of the tool center point. This can be a significant advantage in case of complex or limited work space constellations, e.g. with obstacles that – in case of a kinematic redundancy – can be avoided. A further advantage of redundant robot kinematics is their enhanced capability in terms of interaction with the environment. Based on position controlled standard axes, the redundant axis of a robot can be operated in force-control mode, allowing the operator to define a pose and a reaction force at the same time.

Cooperative robots offer interesting opportunities for future robot applications. They enable systems to hold a work piece with one arm and process it with the other. In such a configuration, both location and orientation of the work piece can be freely chosen within the workspace, even allowing the work piece being moved during processing. Robots with multiple arms also have the capability to handle large objects cooperatively (see [9] for current examples and [12] for early work).

Figure 4. *Human-like Cooperative Robot Arms [Motoman]*

Figure 5. *Handling of large Objects with Cooperative Robot Arms [12]*

Favourably the multiple robot arms are controlled by a single robot controller, ensuring a coordinated and collision-free motion of the robots involved. Dual robot arms share major characteristics with human labourers and might therefore offer opportunities to replace or assist human workers.

3.6 Advanced Sensor Performance and Sensor Fusion

Classical industrial robots are equipped with a limited number of sensors. However, increased sensor capabilities along with a significant reduction in sensor prices will pave the way for a higher level of sensor equipment within robot systems in the future. Increasing numbers of installed force-/torque sensors will e.g. extend the fields of application for robots from simple position control tasks to force-sensitive interactions. Hybrid sensors will allow for greater flexibility as well as for an increased overall sensitivity of future robot systems. Multisensory perception still means a big challenge in terms of data processing and interpretation but it also offers interesting perspectives towards sensitive robot systems with a higher level of autonomy. Combinations of vision, laser and photoelectric sensors will provide a reliable mapping of the robot's environment and will – by this means – allow for more precise, more flexible and safer robot operations.

3.7 Energy Efficiency

In the past, only little attention has been spent by the robotics community on the aspect of energy consumption. However, as the global manufacturing industry progressively adopts environmental-friendly manufacturing techniques, robots will be more and more judged by their energy consumption and energy efficiency (see e.g. [13]).

Optimisations will address the following measures/areas:

- Motion trajectory
- Work piece position / Cell layout
- Tuning of operation speed and accelerations
- Standby strategies
- Individual component optimisation
- Energy recuperation

However, some of the optimisations will have task specific aspects which will require the specific knowledge of the operator. It seems obvious that robot suppliers will have to develop intelligent assistance functions that allow robot operators to optimize the energy consumption of their system, with respect to their specific demands and diverse knowledge levels of robot operators.

3.8 Service Robotics becomes Innovation Motor for Industrial Robotics

Until recently, mobile robot systems – although being quite frequently discussed and described in the media – had only a minor share in the overall robotics market. Driven by home and military applications, the number of installed systems has dramatically increased during the last few years. Global market outlooks (as shown in Figure 6) predict extreme growth rates for service robots already for the near future. This development provides promising perspectives to the field of industrial robots, since all the technology used in service robots will become easily available and – by the economy of scale – low cost. By this means, service robotics may become an important innovation driver for industrial robotics.

3.9 Human-Robot Collaboration

Robots are particularly advantageous in context with recurring tasks. By contrast, human workers have unique cognitive skills when it

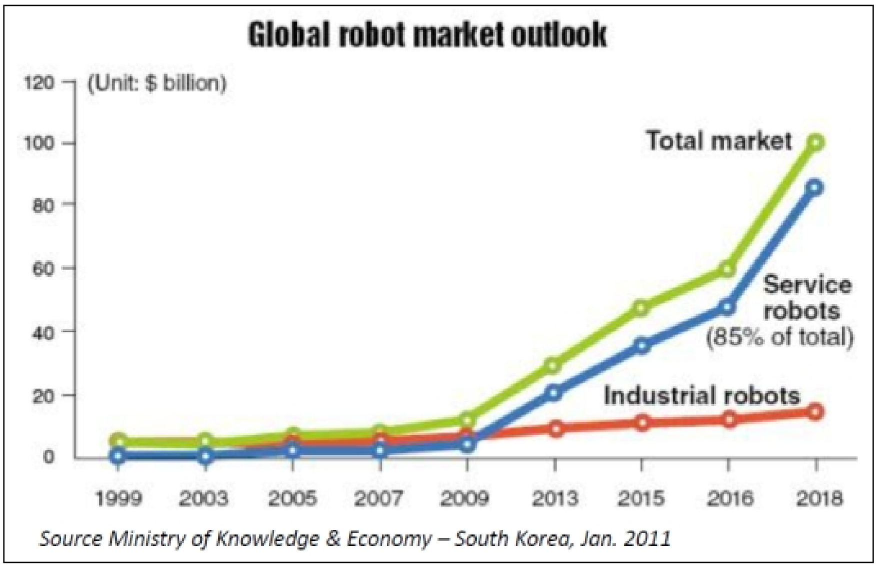

Figure 6. *Global robot market outlook [Ministry of Knowledge and Economy, South Korea, 2011]*

Figure 7. *Human-Robot Interaction [14]*

comes to problem solving and situation-related responses. The cooperation of humans and robots will combine these strengths in the future, such that complex and even non-recurring tasks can be performed in a more economical manner.

As many of the safety-related problems have been solved [8], the human-robot collaboration might soon help industrial robots to gain a higher share in non-typical applications such as:

- Food processing industry
- Medical applications
- Small and medium sized enterprises and
- Entertainment applications.

4 Conclusions and Outlook

The ability of industrial robot systems to improve the quality and efficiency of processes has made them an irreplaceable part of modern production.

As a consequence, the general perspectives for the robotics industry are promising: rapid technological growth in all relevant areas will significantly foster the advancement of industrial robotics in the near future. Thus, robots will find their way into ever increasing levels of complex manufacturing tasks. In the long run, robot systems are likely to transform from task specific devices to highly flexible, ubiquitous helpers in modern production environments.

However, the growing global competition and increasingly strong saturation effects in classical markets, forces robot manufacturers to strengthen their innovation efforts. Even more, the generation of innovations alone will not be sufficient. With respect to the shortening of product development cycles, a structured approach to this innovation challenge is becoming more and more essential.

In this context, the analysis of innovation drivers as well as the identification of potential fields of innovation – as they are presented in this article – can serve as a helpful tool for the identification of relevant research and development areas. Thus, the considerations presented, can not only support original robot equipment manufacturers but can also help component and system suppliers to get a clearer picture of future robot systems and related business opportunities.

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Pomen inovacij v prihodnosti industrijske robotike

Razširjeni povzetek: Prispevek se na podlagi objav večjih robotskih proizvajalcev in lastnih ocen avtorja osredotoča na možnosti in potrebe uvajanja inovacij v današnji in prihodnji razvoj industrijske robotike. Obravnava tudi glavne razloge za uvajanje inovacij v robotiko kakor tudi razvrstitev in razlago glavnih inovacij na področju robotike. Prispevek zato lahko služi kot koristno orodje za identifikacijo ustreznih raziskovalnih in razvojnih področij v prihodnosti robotike in je lahko v pomoč dobaviteljem komponent in sistemov, da bi dobili jasnejšo sliko o prihodnjih robotskih sistemih.

Glede na prvo resno uporabo v industrijskem okolju v zgodnjih 70-ih letih prejšnjega stoletja robotiki ne moremo več prisoditi značilnih lastnosti nastajajoče oz. nove tehnologije. Pravzaprav so roboti postali standardna oprema v sodobnih proizvodnih okoljih, ki zagotavljajo hitro in zanesljivo izvajanje rutinskih operacij, kot so npr. standardne »pick-and-place« naloge v montažnem procesu. Zato se proizvajalci klasičnih robotskih konfiguracij vse bolj soočajo z vedno močnejšo konkurenco na trgu, kar jih sili v osvajanje novih trgov z uvajanjem inovativnih rešitev ter novih tehnologij.

Medtem ko so morali proizvajalci robotov v preteklosti razvijati večji del strojne opreme sami, bodo v prihodnje vse bolj in bolj uporabljali razvojne dosežke drugih visokotehnoloških področij, kot so mobilne komunikacije, igralne konzole in podobne rešitve. Čeprav bo pogosto potrebna prilagoditev teh komponent industrijskim aplikacijam robotskih sistemov, bodo stroški bistveno nižji v primerjavi s stroški polnega financiranja lastnega razvoja. Glavna področja nujnega uvajanja inovacij v robotiki so podrobneje predstavljena v poglavju 3 oz. njegovih podpoglavjih.

Očitno je namreč, da bodo inovacije igrale ključno vlogo v prihodnosti robotike pri osvajanju tehnoloških prednosti na vse bolj globaliziranem trgu. V prispevku so glavni gonilniki oz. možnosti ter potrebe po uvajanju inovacij predstavljeni z vidika različnih aplikacij in scenarijev v sodobni robotiki. Povečan obseg aplikacij zagotavlja niše za specializirana podjetja, pa tudi potencial rasti za glavne akterje na trgu.

Ključne besede: *industrijska robotika, inovacije v robotiki, inovativni gonilniki v robotiki, aplikacije v robotiki, trendi v robotiki*