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# INDUSTRIAL ROBOTS MEET INDUSTRY 4.0

## IPARI ROBOTOK AZ IPAR 4.0 ÍGÉNYEIHEZ

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**_Abstract_**

*The industrial robot market has been changing significantly over the past few years. Today, the development towards Industry 4.0 and digital future factories is confronting a raising amount of industrial companies with new challenges. Industry 4.0 allows the individualization of products referred to as mass customization. In the future smart factories will be able to produce small batch sizes economically. Automation solutions, especially new kinds of robotic technologies will play a vital role in this fourth industrial revolution in terms of efficiency and productivity. Nevertheless, a comprehensive analysis of how robot technology contributes to Industry 4.0 is still lacking. In this paper a practical view on the ongoing changes will be presented and the potential of smart collaborative robots which are fully integrated in the digital infrastructure of future factories is presented.*

***Keywords:*** *automation, robots, industrial revolution, Industry 4.0, collaborative robots, smart factory,*

**_Absztrakt_**

*Az ipari robotpiac jelentősen változott az elmúlt években. Napjainkban az Ipar 4.0 és az intelligens gyárak felé irányuló fejlődés egyre nagyobb kihívásokkal szembesíti az ipari vállalatokat. Az Ipar 4.0 lehetővé teszi a termékek testre szabását, amelyeket tömegméretezésnek neveznek. A jövőben, az intelligens gyárakban a legkisebb tételeket lehet majd gazdaságosan gyártani. Az automatizálási megoldások, különösen az új típusú robottechnikák fontos szerepet játszanak a hatékonyság és a termelékenység növelésében. Ennek ellenére továbbra is hiányzik egy olyan átfogó elemzés mely tárgyalja, a robottechnika hozzájárulását az Ipar 4.0 koncepciójához. A cikkben gyakorlati szempontból kívánjuk megfogalmazni a folyamatban lévő változásokat és megmutatni az intelligens együttműködő robotok azon lehetőségeit, amelyekkel integrálhatók a jövőbeli gyárak digitális infrastruktúrájába.*

***Kulcsszavak:*** *Ipar 4.0, együttműködő robotok, intelligens digitális gyár, negyedik ipari forradalom*

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## INTRODUCTION

Today's business environment is shaped by the ongoing globalization and the increasing use of internet-based digital technologies in production. In history of industry, three revolutions have turned the branch on its head and did fundamentally change the business environment. Considering recent developments, it is becoming extremely difficult to ignore the dawn of another paradigm shift. In the new global economy, the digitization has become a central issue for industrial manufacturers.

Initiatives of the leading industrial countries promote a new era of manufacturing. For example, the German 'Industrie 4.0' or the American 'Industrial Internet' refer to the use of smart intelligent machines and other digital assets linked in a company-wide software-based infrastructure [7, 21]. A much-debated question is whether this development is a revolution or simple evolution of existing technologies as automation, robots and the use of IT initially came up during the 1960's [10, 18]. However, the ongoing convergence of operational technology and information technology promises enormous gains in efficiency and productivity [26]. As the industrial sector is regarded to as a key driver of the economy, leading industrial country's need to drive this change and adapt to the digital environment. Based on a short historical summary of past industrial revolutions this article provides an overview about the ongoing changes on international shop floors in terms of Industry 4.0. Given the fact that a systematic and detailed understanding of how automation and robots contribute to Industry 4.0 is still lacking, the focus will then be placed on robotic technology in Industry 4.0.

## FROM STEAM ENGINE TO DIGITIZATION

In history, mechanization, electricity and most recently electronics, information and automation technology have triggered three game changing revolutions. The first industrial revolution at the end of the 18th century followed the introduction of water- and steam-powered mechanical manufacturing facilities. Later, in the 19th century the second industrial revolution was caused by the electrically-powered mass production using assembly lines and the division of labour. The third industrial revolution began in the 1970's with the implementation of complex electronics and information technology (IT) on the shop floor to achieve increased automation in industrial processes [1]. They all have in common is that they had a major impact on the industrial value creation. The figure of the German Research Centre for Artificial Intelligence (AI), shows the development towards the fourth industrial revolution and the chronological sequence, as seen on Figure 1.

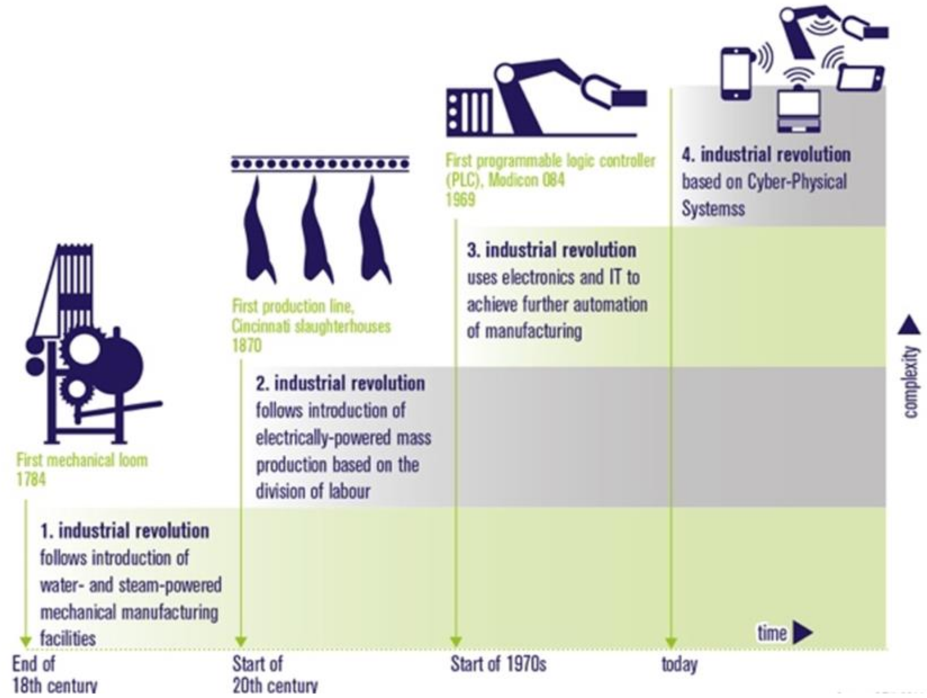


**Figure 1**: History of Industrial Revolutions [1]

In the course of digitization, the fourth industrial revolution now aims to connect the digital and virtual world of computer technology with the world of industrial production. This development is driven by and based on the Internet of Things (IoT). In the industrial application, the IoT enables the internet based interaction and collaboration within global networks and transcends the present borders and limits of companies. Generally speaking the IoT describes the connection of people, objects and machines to the internet [25]. Those smart, connected devices are on the rise. A glance at current statistics shows that the adoption of connected devices has been increasing over the past few years (see: Figure 2.). In 2015 the total number of connected units was about 5 billion. If this trend continues, this number is estimated to increase by 2020 to more than 20 billion connected devices [22].

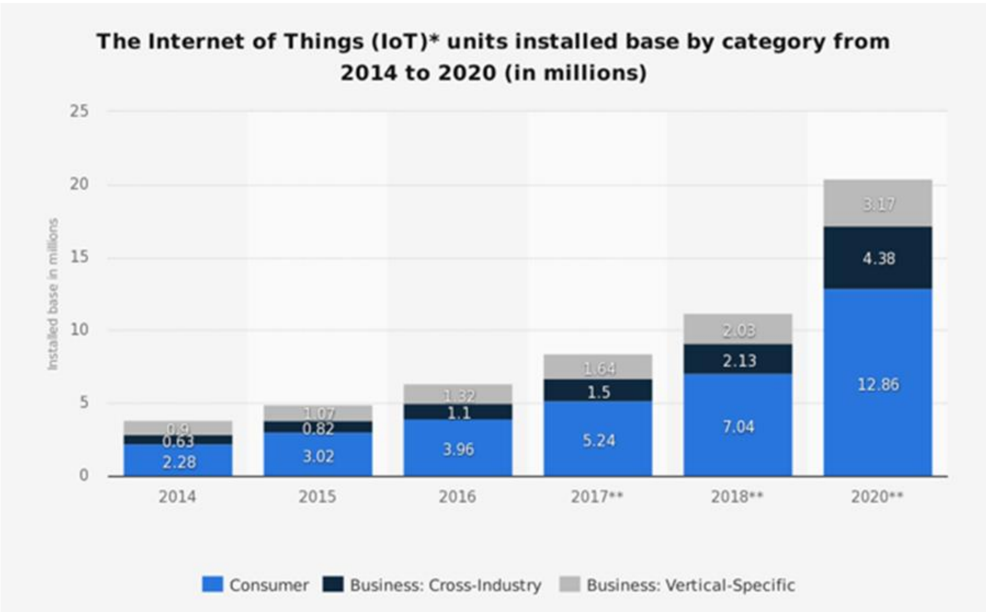


**Figure 2**: IoT units installed 2014 - 2020 [22]

According to Matharu et al. [15] the "*Internet of Things (IoT) can certainly be defined as the biggest revolution in the making of the IT industry. The IoT will impact our living style, the way we consume energy and all our day-to-day activities* [15]." These impacts are now so widespread that they also affect industrial value creation. The new opportunities cause significant changes in the market as the converging information and operational technology allows completely new solutions including product, service and process innovations.

## INDUSTRY 4.0

Industry 4.0 refers to the industrial application of IoT technologies and is an initiative led by the German government to accelerate the industrial digitization. Taking a closer look at the industrial sector, the global competition has intensified and Germany is not the only country to have recognized the trend to deploy the Internet of Things and Services in manufacturing [1]. The 'Made in China 2025' or 'Industrial Internet of Things' programs in the Chinese and American manufacturing industry are for example two nearly similar approaches of other leading industrial nations.

The vision of Industry 4.0 and comparable concepts is to construct an open, smart manufacturing platform for industrial networked applications [1, 3]. In Germany, the development towards Industry 4.0 already has a noticeable influence on traditional business models and manufacturers cannot afford to close their eyes to reality and ignore the ongoing industrial transformation [6, 24]. The constantly changing market and customer requirements are confronting manufacturers with new challenges and affect almost every strategic decision. With the realization of the vision 'Industry 4.0' major changes will occur not only for factories but also for individuals.

### The Impact of Industry 4.0

Cutting-edge manufacturing solutions are the upcoming trend in industrial value creation. In the field of technologies those which allow higher efficiency, productivity and transparency have become the focus of attention

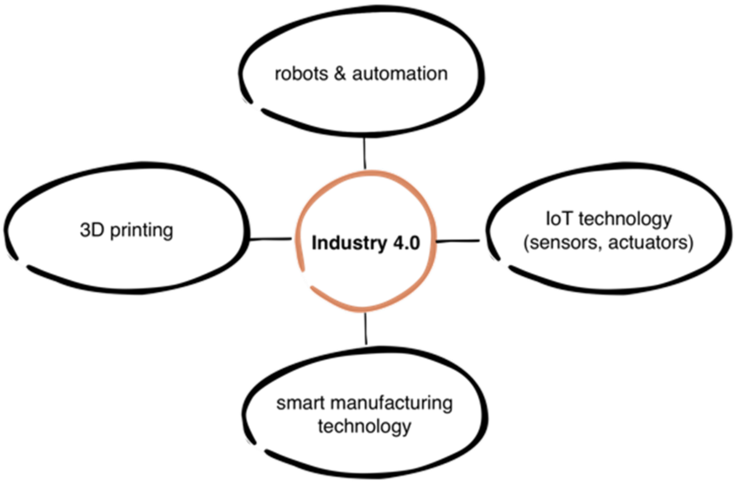


**Figure 3:** Industry 4.0-related Technologies (made by author)

As the figure shows, the solutions include devices such as sensors and actuators, robots, 3D-printers and manufacturing devices (such as milling-, turning-, grinding- machines etc.,) and assembly line components [5, 26]. Unlike the factories today, Industry 4.0-factories employ a completely new approach to production and transform into complex and digitized production facilities with highly automated value chains [1, 3, 20]. All assets are equipped with sensors and actuators and share data with higher level systems [4]. This convergence of the operational technology and modern information technology results in so called cyber-physical systems (CPS), which are referred to as the driving force behind the fourth industrial revolution [6, 26].

In Industry 4.0 factories become smart and enable the fast response to market changes through flexible and demand-driven production of goods. In those smart factories the work pieces, tools, machines and robots are capable of autonomously exchanging information, triggering actions and controlling each other independently, which holds a huge potential for several improvements [1, 4]. The CPS are constantly connected, which is why the data gathered by various sensors can be used to cut costs and optimize processes [11]. A new generation of 'smart' products shares information about the status, history and the target state which enables them to manage their own production process [1, 6]. Another interesting part are new forms of human machine interaction. Workers could be supported with the information they need 'on demand' and would be able to make the right decision in every possible situation. The smart technologies will help manufacturers to increase their competitiveness through further efficiency gains and flexible fabrication of high quality products [1, 6]. Using advanced technology, companies can benefit from entirely new supply chain structures with higher equipment efficiency and flexible processes which offers strategic advantages such as the better handling of complex goods, shorter time to market and manufacturing on demand [8]. In future smart factories, batch sizes starting from one can be manufactured economically which allows individual customer needs to be met, additionally the dynamic business and engineering processes enable last-minute changes to production [1]. This will aide the process of mass-customisation.

### Horizontal and Vertical Integration

Industry 4.0 is a topic with a strong interdisciplinary character. This paradigm shift in the traditional manufacturing industry requires a holistic and sustainable digital reorientation of the entire corporation, especially in the field of factory organization.

To realize the vision of smart factories, the holistic integration of all machines into a company-wide digital infrastructure is necessary. In smart factories manufacturing processes, but also the engineering and business processes from the 'office floor' need to be integrated in the digital infrastructure [25]. In order to meet the vision of an open, smart manufacturing platform the manufacturing systems need to be vertically networked and horizontally connected [1].

Vertical integration in this context refers to the connection of business and manufacturing processes including resources such as material across all levels of the organization [2]. Process data is collected and analysed in real-time, to react and adapt to environmental changes such as unexpected production stops or failures in the supply of material. The production lines are constantly connected and always optimally adjusted to the specific situation. The smart factory is driven and controlled by real-time data and therefore guarantees that all necessary decisions can be taken as efficiently and rapidly as possible.

The horizontal integration moreover describes the connection of machines and production systems across company borders [2]. All stages of the supply chain share data and communicate in a digital production network.

## COLLABORATIVE ROBOT TECHNOLOGY

The development towards smart factories goes hand in hand with higher degrees of automation. Surveys such as conducted by the VDE (*Verband der Elektrotechnik, Elektronik und Informationstechnik*) [22] have shown, that in the future automation is seen to be the most important key technology for the companies interviewed. High rates of automation are often associated with the replacement of human labour by machines. Industry 4.0 in contrast, rather aims at the support of human workers using new technologies. Therefore, automation and in this regard state of the art robot technology represent crucial elements of Industry 4.0.

Previous research indicates, that robots are still the key instruments in production strategies of flexible automation [16]. The Boston Consulting Group (BCG) estimates the global spending on industrial robotics to grow rapidly in the years to come. The statistic shows a spending of 16.7 billion U.S. dollars in 2020 and a total of 24 billion U.S. dollars in the year 2025 (see: Figure 4).

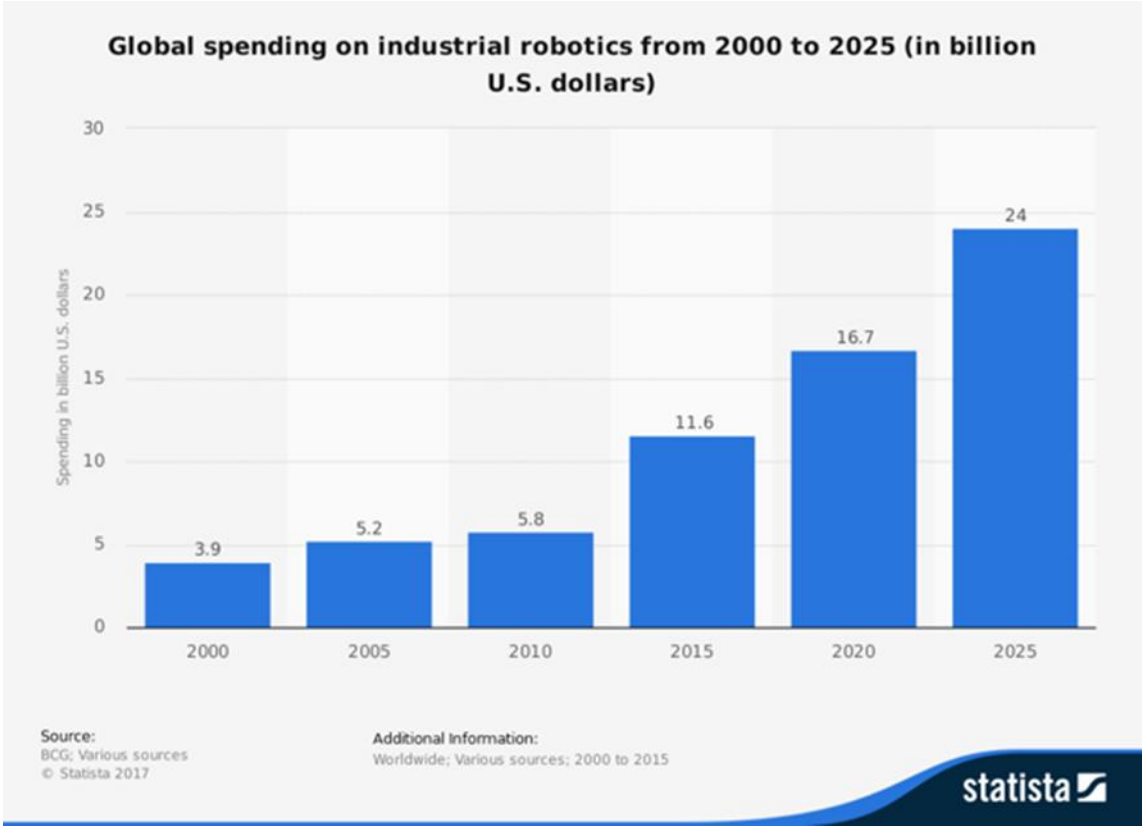


**Figure 4**: Global Spendings Industrial Robotics, according to [23]

Nonetheless, trying to reach ever higher levels of automation the interaction between human and machines becomes a central issue [3]. If robots are also cooperating with other activities that are distanced far away in space then time delay problems occur. Today many researches are made to handle the problem of time delay in control [27]. Today, many of the production processes cannot be easily automated – collaborative robots are able to fill these gaps [13]. In many cases such as assembly systems, parts of the process can only be automated very difficultly or the automation is not economical. These can be complex tasks that are changing rapidly, tasks that need two hands and a delicate hand-eye coordination, etc. These parts of the assembly line should be conducted by human workers. However many parts of almost any production can be easily and cheaply automated. In order to satisfy both demands, hybrid lines should be deployed. In these production line, however, conventional robots cannot be used. To satisfy this place in the market new robots were introduced that can work besides human workers. Especially the flexible mass production of individual products places new demands on the automation technology.

Recently there has been an increasing interest in those so called cobots. Traditionally a robot is defined by the IFR as „an automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile for use in industrial applications“[11]. In the age of Industry 4.0 computers and robotics come together in a completely new manner.

Collaborative robots enable new forms of human machine interaction. A cobot can be simply defined as „a computer controlled robot device designed to assist a person“[18]. These new collaborative robots are more flexible and are capable of learning and interact with machines and human. In contrast to traditional robots the cobots can learn new tasks through training by demonstration instead of cost-intensive programming [12].

In the field of factory automation adaptive robots create new efficiencies and change how companies produce goods and organize the shop floor [16]. For example the process costs can be reduced as the collaboration increases the productivity and efficiency and the robot requires less space as it is not isolated from the operator [8]. Unlike traditional robots, cobots need no fences around because sensors and visual systems guarantee that the robot stops before colliding with the operator [12]. This enables robots to perform tasks as humans do and allows human workers to work closely with robots [12]. Human workers can focus on complex tasks where „intelligence and dexterity “is required, in the opposite case the robots complete the tasks, which are exhausting or dangerous for the human [8].

Compared to traditional robots, collaborative robots show several benefits. They are smaller, smarter and safer. In addition, they are cheaper than stationary robots and can also be used as mobile units [13]. This flexibility enables manufacturers to use the cobot on multiple lines and easily reprogram it if necessary [12]. There are also the other side of the coin. These collaborative robots have different drawback as well. If they are compared to a conventional robots with the same capabilities we find the following: there prices are much higher because the sensorial background (sometimes even camera integration is also applied) and also the developed software background that ensures the required safety for human-robot collaboration. Their productivity is usually lags far behind conventional robots. Robots working behind a safety area (fence) can apply their full capabilities in speed acceleration and payload. Collaborative robots cannot utilise these, to ensure that the robots stops if it collides with a human. This way they work with a much slower speed that are even reduced further if a human approaches the robots. The robot has to stop if the worker enters its working envelope. This reduces the productivity of the robot considerably. The payload has to be reduced in order to have the robot safe for human collision. The so called light weight robots are design the way, that even if it hits a human they would rather brake than harm the worker. Taken these facts into consideration a human-robot production line is can be a well-functioning solution for new tasks.

## CONCLUSION

Industry 4.0 has a major impact on the manufacturing industry. The paper reviews the ongoing changes and shows the potential of smart factories in the production sector. Industry 4.0 enables increased individualization of products, shorter time to market and boosts in terms of productivity, flexibility and quality.

Manufactures, not only in Germany must critically rethink their business models and strategies, keeping in mind the new technologies from the different fields. Looking at Industry 4.0 in practical context the holistic integration can be taken as the central requirement to benefit from the opportunities. The complex implementation will be one of the key tasks in the years to come.

In this new industrial world, robots will play an important role and smart and collaborative robots are on the rise and stepwise will find their way on the shop floor of manufacturing companies.

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