ROBOTICS 2010
DEVELOPMENT OF ROBOTICS AND AUTOMATION IN INDUSTRY[⊗]

ROBOTIKA 2010
A ROBOTIKA ÉS AZ AUTOMATIZÁLÁS IPARI FEJLŐDÉSE

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Abstract: *The technical development of the industrial robots is one of the most dynamic development fields of the mechanical engineering. The universal applicability and the permanent development of new robot models, size classes and load categories, is the base for this dynamics. The article describes the evolution of the industrial robots being with the first economic applications in the sixties. As in the case of all industry products, the economic efficiently of capital goods is the main accelerating element for the growth. It is the target to describe the different motivations for investment in robot technologies in different decades.*
At this time, the first applications of robots took place in the lines of business, where human has reached his limits with his physical abilities. The motivation was quality and reproducibility for the use of robots in the eighties. There were about 150 robot manufacturers worldwide at that time. The robot became an industrial series product in the nineties. The efficiency of the application and the price of the robot were responsible for the growing robot population. Since turning of the millennium the technical further development, of for example vision-systems, opens up new fields of applications. Today approximately 10 robot supplier worldwide can follow the speed of the markets.

Keywords: *industrial robots, robot applications, market requirements, evolution of robot design and manufacturing.*

Kivonat: *Az ipari robotok műszaki-technikai fejlődése a gépészeti-mechatronikai tudományos egyik legdinamikusabban fejlődő területe. A fejlődés fő hajtóereje az ipari robotok sokrétű alkalmazhatósága, a teher kategóriák kiterjedt volta, valamint a megnövekedő méretek, és teljesítmények. A szerző célja bemutatni az ipari robotok alkalmazásának fejlődését a 60-as évektől. Mint egyéb ipari termék esetében, a robotok esetében is a termelés hatékonyságának növelése a fő mozgatóerő. Az elmúlt évtizedekben ez volt az ipari robotok fejlesztésének fő motorja. Az ipari robotok első alkalmazásait a gazdaság oly területein figyelhetjük meg, ahol az ember a fizikai teljesítőképessége határára ért. A 80-as években az ipari robotok alkalmazását az előállított termékek minősége javításának célja serkentette. Ebben az időben 150 robotgyártó cég működött szerte a világon. A robotok sorozatgyártására a 90-es évekig kellett várni. A robotalkalmazások hatékonysága, és a robotok ára lehetővé tette a robot-populációk erőteljes növekedését. Az Ezredfordulón a további fejlesztések, mint például a kamera-rendszerek új lehetséges alkalmazások területeit nyitották meg. Napjainkban kb. 10 robotfejlesztő-, és gyártó ország képes megfelelni a piac egyre növekvő elvárásainak.*

Kulcsszavak: *ipari robotok, robot alkalmazása, piaci követelmények, a robottervezés és gyártás fejlődése.*

I. INTRODUCTION

Military Robots and Industrial Robot have a common history. Many developments came out of the military laboratories in the beginning of last century. At this time the governments invest big parts of their budgets in military research and development.

The first independent operating systems where used in military applications. Robots in military are still “special machines”, build in small lots and very dedicated for their application. Only drones and minesweeping robots are used in larger lots in military applications.

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Today industrial robots are mass production machines. The mechanical types, drives, controller, sensors and applications are the key items in their development.

Robots in Industry are categorized into four main mechanical robot- types:

The linear-type- robot, the scara-type robot, the articulated-type-robot, and, the delta-type-robot. In the statistic of the International Federation of Robotic (IFR Statistic), the Delta-type robot is not counted because this design is a relative new product on the market.

Starting with the hydraulic Robots the mechanical units where dominated by the dimensions of the hydraulic cylinders and drives. These robots were heavy, slow and very expensive compared with machines today.

With the progress further development on the servo drives, most robots change their mechanical units into the articulated design. The IFR data’s shows, that the market share of articulated - and delta robots growths fast.

Scara robots and linear robot are also using servo motors, but because of their disadvantage in case of degrees of freedom, is the market share of this designs shrinking.

The revolution in the electronic Industry is another indicator for development in robotics. In the eighties, robot became slower if the demand for periphery communication increased, because the capacity of the CPU could not handle motion control and communication.

Current generation of robot controllers is based on dual-core architectures. Motion control and data communications are kept separate and processing is distributed over a pair of CPUs.

Sensors, for example, let robots see, feel and let robots work safety in there environment.

Development of sensors did not influence the robot development direct, but the sensor technologies opens robotics a huge application market.

Applications also define development of robots. In the eighties the automotive industry demands approximately 90% of the robots market. Most for spot-welding applications. So Robot supplier build robot with focus on point to point movements and payload of 70 to 90 kg.

Later follows arc-welding and handling applications outside the car manufacturer with different requests. With this, the robot design starts to diversify up to the various models today.

II. LITERATURE REVIEW

The literature provided many publications to the development of robotics and automation in industry. In case of military robots, the literature is more orientated to robotized weapon systems and not so much to the common history of industrial and military robots. Szabolcsi in [8] paying attention to this subjects in different congresses [9], lectures [10] and conferences [11].

Appleton [1], introduced in his book „Industrieroboter Anwendungen“, design, work-envelopes and ranges for application. Special the difference between serial and parallel structures for industrial robots.

Spur [2] focused in his publication more on the description of the first controller architecture, programing and data exchange.

The development of motors brought the change from hydraulic to electrical driven robots. Today the investigations conducted at the ISW Institute, Stuttgart, showed that direct drives are, in principle, feasible in the case of industrial robots, as was documented in, for example, the dissertation entitled “Regulation of high-speed, electric-servomotor, direct drives on manufacturing systems” described by Fahrbach [6].

Sensor technology was on of the topics on the 3rd International Symposium on Industrial Robotics, Zürich 1973 [3]. Although the first “robot equipped with a pattern-recognition system” was exhibited. They name it “optical orientation system” at this time instead of vision systems today. The industrial use of vision systems has a history of 25 years. In 1994 on the 25th International Symposium on Industrial Robotics in Hannover [4], 3D Vision systems where on the agenda.

Trade magazines publish the spectacular success stories of robotics. For example, robotic cells that automatically handle rose cuttings have been developed in Holland (Figure 4.). Foitzik [7] and Wickham [5] describe application in the flour and food industry.

III. INDUSTRIAL (AND MILITARY) APPLICATIONS OF AUTOMATION AND ROBOTICS

The history of industrial robots goes back just over forty years. The first robots appeared on the industrial landscape in the late 1960s. They are now essential features of every flexible, efficient, manufacturing operation. Although key branches of industry, such as automotive industry, are, of course, already highly automated, the general manufacturing industry, and particularly small, and medium-sized companies, are increasingly taking advantage of the flexible manufacturing operations and opportunities for automation that robots provide.

Automation was spawned by mass production. Segregating manufacturing operations, into sequences of procedures may be regarded as the initial step in that direction. That turned attention toward those procedures that needed the flexibility that only humans could provide and those that could be automated. That advance was accompanied by the employment of robots in, for example, foundries, or for easing the handling of heavy loads (Figure 1.)

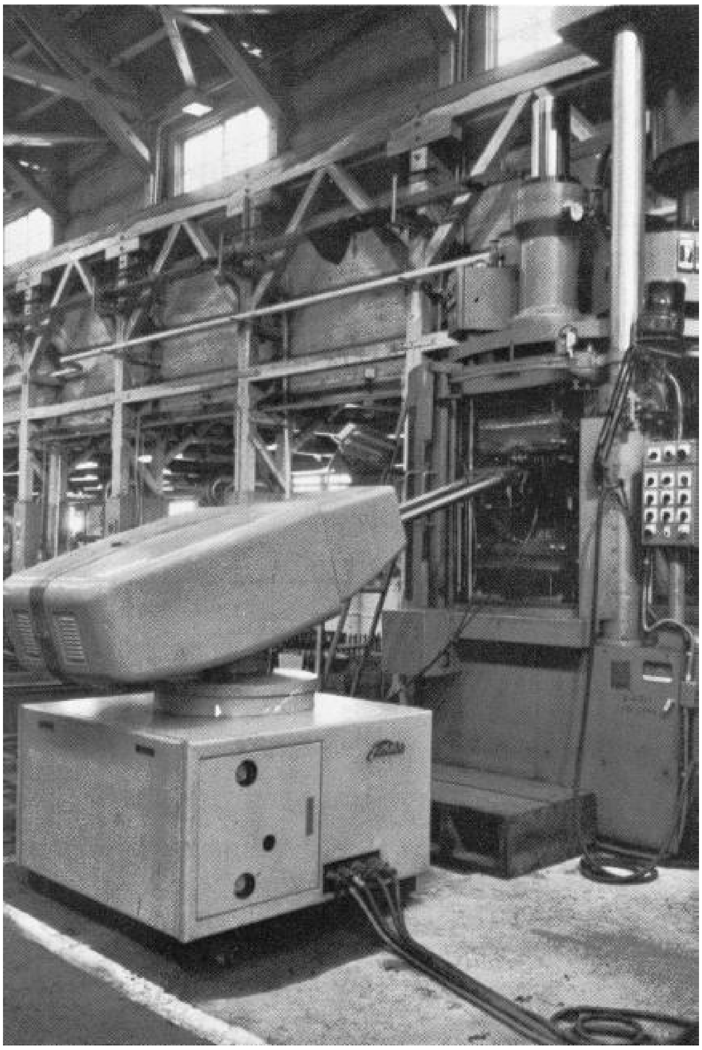

Figure 1. Industrial robot, Japan, 1973.

A highly significant technological advance was the transition from hydraulic robots to robots driven by electric motors. Both types of drives remained in use in parallel for quite a while. The final generation of hydraulic robots was used in spray-painting applications, where hydraulic drives were retained for years after they had all but disappeared elsewhere, in order to prevent explosions. Lissmac's 1990s attempt to revive hydraulic drives on robots designed to handle heavy payloads failed. Its project, which was aimed at developing a robot capable of handling 1,000 kg payloads for the construction industry, never got beyond the prototype stage.

The development of servomotors that could be finely regulated and controlled to suit the loads involved meant that the ideal choice of drive system for industrial robots had finally been found. However, direct drives, i.e., servomotors coupled to gear transmissions, became standard equipment on Scara and delta robots only. The forces and accelerations that occur in the case of industrial robots equipped with articulated-arm kinematics continue to necessitate employment of precision transmissions. Investigations conducted at the ISW-Institute, Stuttgart, showed that direct drives are, in principle, feasible in the case of industrial robots, as was documented in, for example, the dissertation entitled “Regulation of high-speed, electric-servomotor, direct drives on manufacturing systems” [6]. However, the robot-weight/payload ratios of large robots rapidly reach the point where their implementation on large robots becomes impractical.

A noteworthy recent advance is the employment of a pair of servomotors on each axis in order to improve robot dynamics, an approach that is currently being exploited in two application areas. On high-payload robots (Fanuc M-2000iA and Kuka KR1000), dual-servomotor drives yield faster accelerations and decelerations. The first robot equipped with dual-servomotor technology to be employed in industrial applications was the Fanuc M-430iA, a robot that was specially developed for use in the food-processing industry and designed to yield very high pick rates. A special feature of its drive system was the use of a pair of high-torque, high-speed servomotors to drive each of its three major axes, whose motions were controlled by a “dual-drive, tandem, torque controller” that allowed attaining very high translation rates on the Fanuc M-430iA/2F. When tested employing a standardized test cycle involving raising its arm 25 mm, driving its arm 300 mm horizontally, and then lowering its arm 25 mm, the latter robot managed 120 cycles per minute for a payload of 1 kg, and 100 cycles per minute for a payload of 2 kg.

Controllers

The best performers of the current generation of robot controllers are based on dual-core architectures. In order to highly accurately control robot gripper trajectories and positioning and be able to process sensor signals and other system data in real time, motion control and data communications are kept separate and processing is distributed over a pair of CPUs, which allows a single controller to run systems having as many as 72 axes. Closer collaborations among machinery manufacturers and robot manufacturers have led to increasing numbers of automated manufacturing cells being offered as standard solutions.

As long as CNC-controllers and robot controllers had differing interfaces and had to be custom tailored to suit particular applications, various solutions, such as employing robots on machine tools, remained proprietary solutions. Nevertheless, for years, systems houses managed to unite both worlds. However, a common control platform is preferred, both by systems houses, since it eases system integration, and by users, since it simplifies dealing with all aspects of system operation. Being able to employ the same type of controller architecture at all of one’s manufacturing plants is a matter of great concern, particularly to multinational companies, who want to, and need to, employ the same machinery at all of their manufacturing plants.

Facilities for controlling simple handling axes or controlling, for example, delta robots, are increasingly being incorporated into the controllers of modern machinery and manufacturing systems. Motional axes are being directly addressed by machinery controllers, particularly in the case of packaging systems that need to very rapidly accomplish picking tasks. Meanwhile, manufacturers of PLCs and CNC-controllers (B & R, Rockwell) are attempting to gain footholds in the world of robot controllers and have began offering common control platforms for simple tasks involving just a few handling axes.

Sensors

Even the first robots were equipped with sensors, since otherwise freely programmable trajectories would have been unrealizable. Whenever sensors are mentioned in conjunction with robotics, the sensors involved are usually ones that allow accomplishing a given task, such as a joining task, in principle, as well as flexibly and gently.

In the early day of robotics, robots did not guide themselves by referencing their positions to their surroundings. In the beginning, position sensors were their sole means for determining their positions. However, as the tasks assigned to them became more complex, more sensors and different types of sensors became necessary for their operation. Major development efforts are currently being devoted to three types of sensors for robotic applications: vision sensors, force-torque sensors, and all sorts of sensors that either affect safety or allow operating robots in tandem.

Image processing, which was a topic for discussion as long ago as the early 1970s and has meanwhile become a separate field of automation technology, currently plays a dominant role. The major task of robotic vision systems is finding and recognizing locations where parts are to be picked up, i.e., positioning and orienting robots' grippers (Figure 2.)

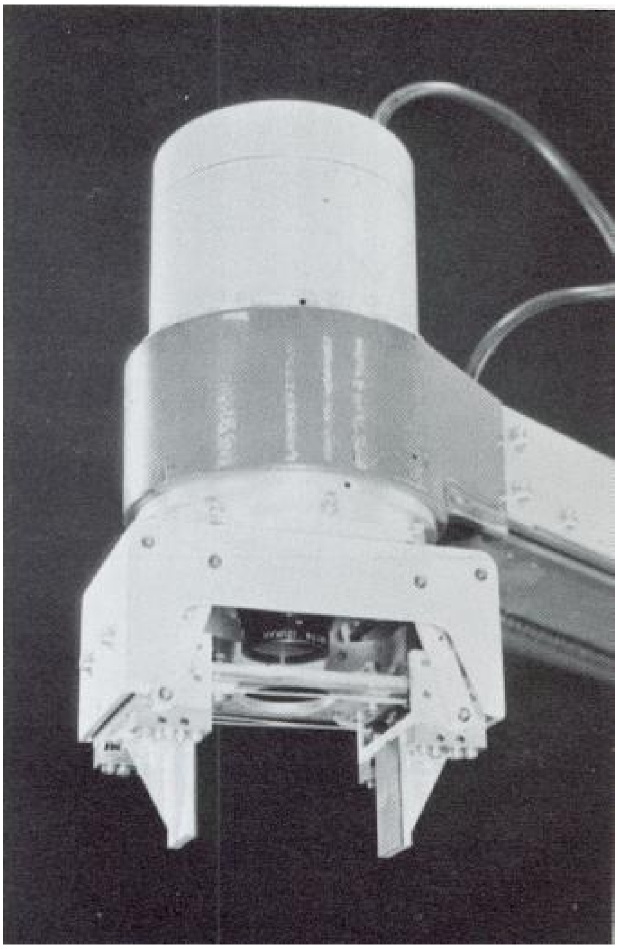

Figure 2. Kammera-Greifer, 1973.

Although the first "robot equipped with a pattern-recognition system" was exhibited at the International Symposium on Industrial Robotics (ISIR) held in Zurich in 1973 [3], it was not until 2000 that significant numbers of vision systems were in use on robotic systems. Meanwhile, robots, for example, delta robots, from all manufacturers are now normally supplied with image-processing systems. Vision systems for use in robotics, such as Fanuc's iRVision, that have been integrated into robot controllers as standard equipment have been available for several years, which eliminates the additional wiring and coordination of vision systems and robot controllers required by stand-alone systems.

Sensors, particularly image-processing sensors, play a particularly decisive role in the configuration of hybrid workstations. Absolutely reliable monitoring systems are essential whenever humans and robots have to share the same workspace. An early development in that area was emergency-shutdown systems, which were initially electromechanically actuated. When the first software-actuated emergency-shutdown systems appeared, both electromechanically actuated and software-actuated systems had to be operated in parallel during a transition period. Software features, such as “high-sensitivity collision detection,” are now standard equipment on industrial robots, and not just those employed in the automotive industry.

Applications

Robots’ initial conquests were the automobile-manufacturing plants of all industrialized countries. Automation degrees far in excess of 90 % are typical in bodywork fabrication and painting. Manufacturing facilities, such as Building 5.4 at Volkswagen’s Wolfsburg plant, were outstanding examples of manufacturing automation back in the early 1990s. The “rigid” robotic automation of those days has meanwhile developed into a system architecture oriented around providing much higher degrees of flexibility. Manufacturing philosophies, such as “just in time” or “just in sequence,” would be infeasible without the aid of flexible robotic systems. Even at Volkswagen’s Dresden plant, where its up-market Phaeton models are manufactured, certain procedures are automatically carried out. For example, spare-tire wells are sealed employing a robotic procedure, windshields and windows are inserted by a robot, and wheels are automatically installed.

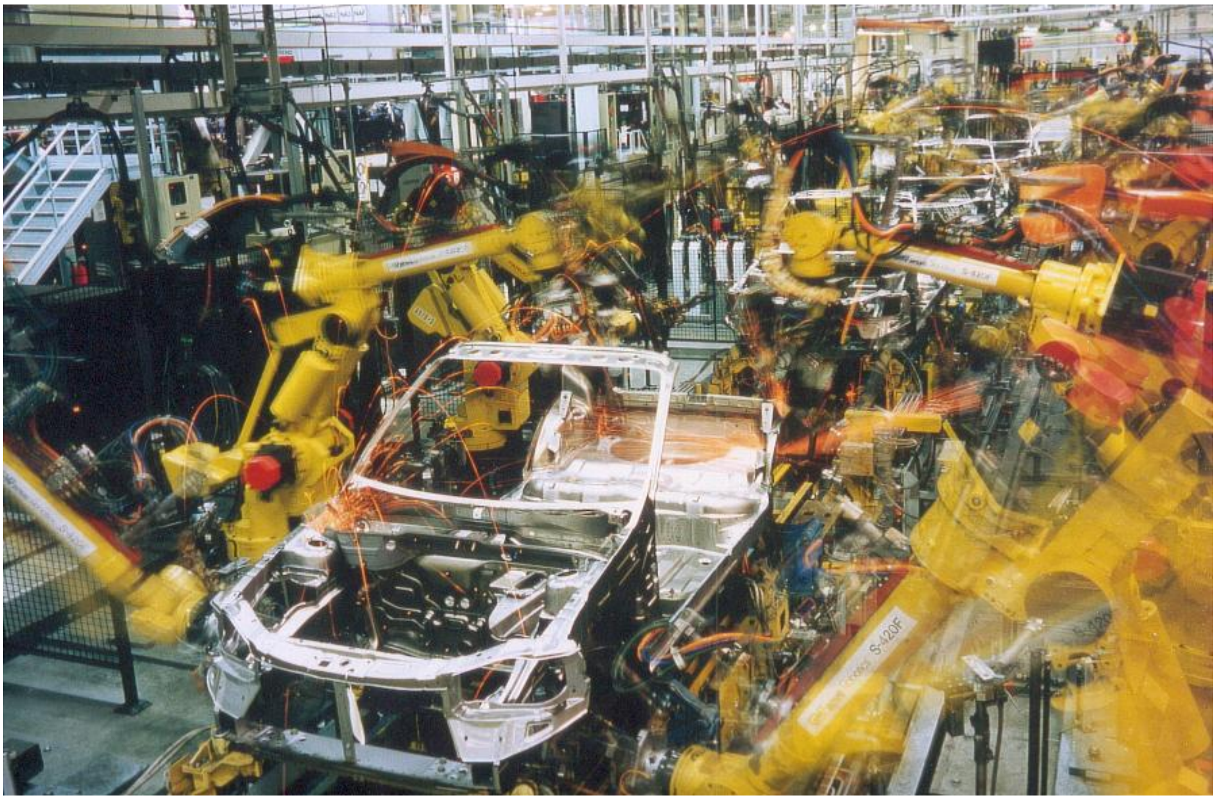

Figure 3. Opel, 1995.

Robot-employment schemes have developed along various lines. In Europe, highly integrated manufacturing cells and lines, where robots have to accomplish highly complex tasks in some cases, are preferred, while in Japan a distribution of tasks within robotic cells, where robots are rarely fully utilized (run at their maximum speeds or called upon to carry their maximum payloads) is usually the rule. Newer bodywork-manufacturing lines show that smaller, slimmer robots are becoming more popular. That trend is being accelerated by the development of lightweight spot-welding tongs that no longer require robots capable of handling payloads of 210 kg and more to handle them and can be operated by “slimline” versions with rated payloads of 80 kg to 100 kg. Manufacturing cells then take up less floor space and manufacturing lines may be slimmed down.

How versatile the employment of robots can be in just about any branch of industry may be illustrated by citing several remarkable examples. Until a few years ago, certain types of robotic applications were unrealizable. Either the engineering prerequisites could not yet be met, or employment of robots would have been uneconomical. Three examples will illustrate the advances that have meanwhile made them realizable.

Thanks to automation, high-wage countries have been able to hang onto some labor-intensive processes and even recover some they had previously lost to low-wage countries. For example, robotic cells that automatically handle rose cuttings have been developed in Holland [7] (Figure 4.). That job was formerly performed manually, but cuttings were being flown back and forth between several “production facilities.” The logistics operations involved were extensive, expensive, and energetically inefficient. Furthermore, cuttings frequently became damaged, so discard rates were high.

Figure 4. “Rose Cutter” Robot.

A Dutch systems house developed and built a robotic solution. Four robots per system handle cuttings, supported by pneumatic-servo transport systems and vision systems. In principle, branches are gauged by the vision systems and their locations on trunks determined. Robots then sever them from trunks and plant the resultant cuttings.

That example demonstrates that automated systems are currently able to recognize and handle even items having irregular contours. The flexibilities of modern articulated-arm robots help make such applications feasible. However, without high-performance controllers and the associated sensors such systems could hardly be economically employed in actual practice.

Remaining competitive was one reason for a Spanish company to automate its processing chain for heads of lettuce [5], from the harvesting stage to shipment (Figure 5.). Its system, which is automated by 68 robots, can process 550,000 heads of lettuce daily. The company had two major reasons for automating the processes involved: it lacked the skilled personnel required and manual processing entailed large variations in workforce utilization. In any event, the company wanted to be able to supply its customers with lettuce of uniformly, high quality. The criteria for this particular solution were close coordinations of the operations of the system’s image-processing systems to those of its robotic and transport systems.

Every one of the system’s robots handles the same tasks. Sensors provide that heads of lettuce that have been placed on conveyors will be transported to the next, free, trimming station, where an image-processing and gauging system determines their diameter and weight. Heads that fail to meet prescribed criteria are sorted out. The image-processing system also locates their heart and suitably controls the system's next robot, which packs the heads of lettuce using a special pneumatic gripper. The system has integrated into it other stations equipped with image-processing systems that provide for continuous, inline, quality control. This automated solution cut labor costs by 80 %. Furthermore, analyses have shown that the rejection rate declined from 20 % to 5 %.

Figure 5. Lettuce sorting. [5]

Automation approaches involving dual-arm robots and multi-arm robotic stations would appear to be similar at first glance. Although dual-arm robots mimic human work habits, it is multi-arm robotic stations, which represent solutions for use on very efficient and flexible systems that have managed to penetrate industrial manufacturing operations. Even though systems incorporating as many as eight robots interfaced to a single controller have been introduced, robotic cells equipped with at most three robots are what are being employed in actual practice. Peripheral axes, such as carousels or conveyor belts, may be readily interfaced to robot controllers. Incorporating more robots into such cells can lead to confusion and loss of control.

Of a fundamentally different nature are systems based on controller solutions or software solutions. Software packages, such as "RobotLink," represent intermediary stages that have proven their worth in, for example, automobile manufacturing operations in Japan and the USA.

Figure 6. Two-arm FANUC Robot, Japan.

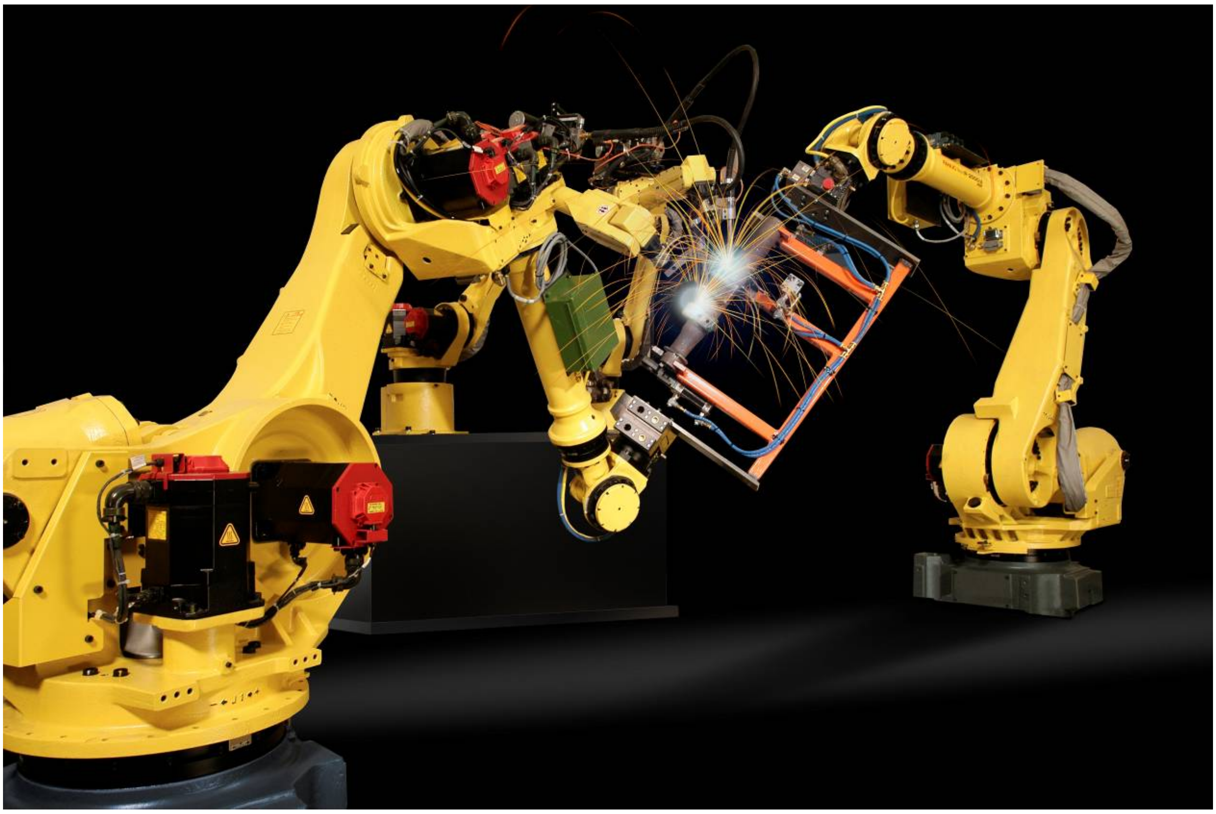

Figure 7. Robot Collaboration.

Such dual-arm robots might well be regarded as precursors of the collaboration models currently under discussion. Even though the definition of “collaboration model” is not interpreted the same way everywhere, it normally implies a collaboration of humans and robots in a common workspace (Figure 7.). In the simplest case, a worker places an item on a robotic cell’s transfer station and the robot reaches into the workspace reserved for humans to pick it up. The aim of such collaboration models is maximizing flexibility and optimally combining human capabilities with the opportunities offered by robots.

In the course of robot development, the idea of having robots equipped with a pair of arms handle tasks in much the same manner as humans has periodically led to the appearance of dual-arm robots. However, neither dual-arm Scara robots nor dual-articulated-arm robots have met with much success in actual practice to date. They have largely served Japanese manufacturers as test systems, even in cases where they, like Fanuc’s dual-arm LR Mate, have been productively employed. The latter dual-arm robot was split down the middle and either half was capable of performing assembly tasks on its own, operating as a five-axis robot. Its manufacturer, Fanuc Robotics, assembled five-axis and six-axis versions of its smallest robot model using such a dual-arm LR Mate robot back in the early 1990s. Numerous of its features, such as a dedicated image-processing system and various sensors, such as force-torque sensors, were tested in actual practice and boosted the degree of automation in that part of Fanuc’s manufacturing operations to around 90 %

SUMMARY, CLOSING REMARKS

The paper shows that DEVELOPMENT OF ROBOTICS AND AUTOMATION IN INDUSTRY seams as a logic process like in other fields of technical products, if the view is from the present back to the past. But if the view is from the past in to the future, the expected evolution of robotics in history is very different to the state of the art today.

This is not a unique characteristic for robotic, this is the result of many parameter who influence this Industry.

Everybody understand the challenge of an estimation into the future in the fields of mobile phones or Personal Computers. Nobody estimated in the sixties, those 50 years later, every Smartphone has more processing power than the shuttle in the Apollo 11 mission, who brings the first human to the moon.

Estimation into the future for industrial goods are even more complex. Special in the field of robotics. Here is the most constant part the mathematic and the technical mechanics.

The influencing variable for robotic are versatile.

Important are the development in electronics, for controller and drives. Also the development of new materials or new sensor techniques and software.

But also additional variable can influence the tendency of robot development. Quality demand of the industry, energy prices in future, shrinking of human population ore other societal reasons.

With the enlargement of the timeframe for the forecast also enlarge the number of influence variable. Forecasting the next five years is may be possible with the assumption of today’s knowledge.

If the forecast of robot development should go up to ten or twenty years, the process of estimation needs to combine different disciplines for the evaluation. Industrial, technical and societal influences have to be analyzed.

For robot developer and for robot user requirements will change and need new models for education. This is the background for the title of the PhD thesis:

“*Robotics in 2030 – A new understanding of the relationship of the robotics and education*”

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