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Automation and robotics in Industry 4.0

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Introduction

It is well known that successful product sales are based on consumer needs. In the 1990s, growing consumer needs were met by introducing technological solutions that enabled mass production. As a result, production lines, the division of finished products into modules that were put together at successive assembly stations, became more common. In the automotive industry, companies that specialized in the production of certain types of car components, e.g. suspensions, seats, exhaust systems, lamps, etc. began to emerge. In this way, a company specializing in the production of lamps could supply them to various car manufacturers. Thus, car factories were transformed into their assembly plants, which could "produce" hundreds of thousands of finished cars in a year. As a result, production costs were significantly reduced, which increased the price competitiveness of a given car model. Unfortunately, such a model of mass production entailed certain consequences. An example of this is a paint shop, where the body of a car was painted on the production line, and the cars were immersed in a pool of a particular color of paint. In this way, only cars of a certain color were produced for several weeks or months. Which, at the stage of an unsaturated demand market, was quite sufficient, since the main criterion the consumer used was the availability of the product and its price.

The concept of Industry 4.0

Today, the consumer market looks very different. The demand for car ownership is already saturated to some extent. Most people in the society can buy a car for themselves because it is widely available. Less affluent people will buy a used car, stable and middle-income people will buy a new car tailored to their needs, and the wealthiest people will buy a car that meets their sophisticated requirements. Thus, it can be concluded that demand is different. What matters is not the number of cars produced, but meeting the customer's needs. Of course, it is not a matter of changing the line and shape of the body, but the color of the paint, the color of the upholstery, additional functionalities such as cruise control, safety systems, the number of airbags, air conditioning, etc. Such adaptation of car manufacturers to individual customer needs entails a change - making the production system more flexible while maintaining mass production. Such an approach to production, which is mass and flexible at the same time, is now called the next industrial revolution - Industry 4.0.

The above-described introduction only illustrates the relationship between the needs of the consumer who expects a specific, often individualized product, and the company that is trying to produce and deliver a specific product to the consumer. On the other hand, this significantly simplified description should be extended to the real world, where the manufacturer has to compete with other companies both in the local and global market. Thus, it is necessary to take into account also the following aspects: manufacturing, economic, logistics and information technology, which intertwine and only together form the whole production system in Industry 4.0.

With the introduction of the industrial revolution, a key element is the integration of automated production systems, which enables better synchronization and management of individual processes. Automation includes not only production, but also logistics, quality control and other areas. Thus, it can be said that Industry 4.0 combines traditional manufacturing processes with modern information technologies, leading to a more efficient, automated and flexible production environment. Such an industry can be divided into several key parts:

1. **Production** – it is responsible for the manufacture of a specific product
2. **Information flow** - this part is divided into several layers. The lowest layer is based on the transmission of information between individual workstations. The middle layer is about the flow of information about: production process, congestion, status of tools, the need to replace or replenish warehouses with finished products or semi-finished products. The top layer is used for the flow of management information, e.g. about the status of machines, job failures, product changes, etc. In the case of large corporations, a global layer can also be distinguished, which is responsible for communication between the production plant, component sub-suppliers, external service companies and production orders.
3. **Material flow -** this is a system that can be divided into two main parts:
   - intra-factory: a flow of materials and tools between warehouses and stations and between stations,
   - external: a flow of materials and tools between the production plant and sub-suppliers.
4. **Supervision** - this part can include aspects such as receiving orders and putting them into production, scheduling tool replacements, scheduling maintenance and replacement of production equipment, crisis management in case of breakdowns, and human capital management.

The above-mentioned parts constitute a single Integrated Automation System that is a comprehensive solution in which various components of the production system, such as machines, equipment, robots, software, sensors and control systems, are closely synchronized and work together. Such a system integrates different layers of production, combining operational (OT - Operational Technology) and information (IT - Information Technology) levels. As a result, information from production lines can be readily available to enterprise management systems. Thus, control of production processes is centralized, allowing monitoring and control from a single location. Centralized control allows rapid response to changes in conditions, minimizing the risk of errors and increasing production efficiency.

Integrated Automation Systems enable the cooperation of various systems, such as MES (Manufacturing Execution System), ERP (Enterprise Resource Planning) or PLM (Product Lifecycle Management), to optimize production management at various levels, including supply chain management, or customer relations. By integrating production and management and supply systems, production systems can be quickly reconfigured in response to changing market conditions, changing product demand, or technological innovations. Thus, Integrated Automation Systems provide the foundation for Industry 4.0, enabling companies to achieve more efficient, flexible and agile manufacturing processes.

Industrial robots integrated into an automated production line play a key role in the manufacturing process. They are used to perform a variety of tasks, from simple and repetitive tasks such as assembly, manipulation, welding, packaging, to more complex and precise operations such as machining or painting. In Industry 4.0, robots are not just physical machines, but intelligent systems capable of cooperation, adaptation to change and integration with other technologies. By integrating robots with vision systems equipped with artificial intelligence technology, it is possible to measure the geometry of workpieces and classify them, for example, as good bad or to be improved/regenerated. It is also possible to classify workpieces by shape and be able to pick different workpieces from a single conveyor belt and stack them in the appropriate pallet, or to detect the stacking of workpieces and pick them at different positions and orientations.

In addition to operating production equipment, in Industry 4.0, industrial robots often work on the same jobs as humans. Collaborative robots are then designed to interact safely with workers. This involves detecting collisions and/or human touching of the robot body and stopping the robot. Then the working skills of the human - adaptability, working with flexible materials, experience - and the robot - repeatability, accuracy, speed, working with heavy loads, contact with hazardous substances - can be used effectively.

It should be further emphasized that the main feature of robots is their programmability and flexibility, which allows them to be quickly adapted to different tasks and products. The use of offline programming and plug-and-produce technology allows rapid implementation and modification of tasks for both the robot and production machines. Modern robots have installed systems to remotely monitor their condition. Thus, integrating them with a surveillance system through IoT (Internet of Things) technology, makes it possible to analyze the collected data and plan maintenance and optimize the production process in terms of energy efficiency, for example.

The work of robots is mainly based on supporting the operation of production machines and equipment, forming an integral part of the production system. In contrast, the production machines and equipment themselves are crucial in Industry 4.0. It is through them that components and products are produced, which are later sold to the consumer. In Industry 3.0, the main focus was on production efficiency. So machines were designed mainly for the production of specific things or even single machining processes. This significantly increased productivity, at the expense of compromising production flexibility. In Industry 4.0, flexibility, diagnostics and communication play a key role. So the nature of the machines used is also changing to ones that have comparable performance, while being easily rearmed and reprogrammed to produce different assortments. So CNC (Computer Numerical Control) machines will play a major role here. The introduction of diagnostic systems for cutting forces, cutting temperatures, or tool wear into these machines allows decisions to be made about changing or sharpening tools, performing maintenance, replacing bearings, or repairing cooling systems.

In the case where the production process consists of several technological operations, it can already be said that there is a manufacturing nest or line. A manufacturing nest, is a set of machines and equipment located in a certain spatial environment, which are aimed at producing a specific product. In this case, the flow of materials between stations is carried out through inter-operational warehouses. When the technological processes are well set up, it is possible to omit intermediate warehouses, and the flow of material takes place directly between stations and is most often implemented by robots. A production line, on the other hand, is a system in which the flow of materials/products passes in line from station to station, and the work cycle is delineated by the longest operation. In such systems, the flow of materials, and therefore the flow time, is significantly reduced. Logistics mainly consists of delivering and receiving pallets of products and semi-finished products after and before processing. However, inside such an Automated Manufacturing System (AMS), the circulation of workpieces is carried out by robots or conveyor lines. In Industry 4.0, a change in the production mix involves retooling and reprogramming of most process stations. On the other hand, changing some parameters of the finished product, e.g. shaft diameter, hole depth, etc., involves only reprogramming one technological device.

In Industry 4.0, the manufacturing systems described above are designed for production flexibility. Machines are used that can be easily reprogrammed or armed for a different production mix. This provides the opportunity for a much faster response to consumer demand without having to change the production system for a long time. The introduction of monitoring of the production process in Automated Manufacturing Systems allows the detection of bottlenecks in the production process and the possibility of redirecting part of the production or technological operations to another machine park. Full monitoring of production processes and the condition of machines will allow effective management of production interruptions (due to the need to service machines and equipment). Based on the information sent by the machines, the superior system supported by human labor and artificial intelligence can determine the appropriate time for servicing and technical inspection before a breakdown occurs. So it is possible to agree on a date with service companies, instead of calling for service in an emergency fish. It should be mentioned here that in the latter case the cost of stopping the line and service is much higher than a scheduled stoppage. This is because with a planned stoppage of the ZSW it is possible to redirect production to another system. On the other hand, in the case of an outage, this is very difficult. Scheduling and executing service outages will result in increased production efficiency with reduced capital expenditures. As a further consequence, it will increase the competitiveness of a given company.

Analyzing the use of robots in Industry 4.0, it is still necessary to mention mobile robots, which are not directly involved in the production process, but are responsible for executing the supply chain of products, semi-finished products or good/used tools. So they play the role of transportation between different points on the production line or in warehouses. Thus, they can significantly increase production efficiency by eliminating the need for manual material handling and optimizing storage space. Such robots are equipped with sensors, cameras and navigation systems, which allows them to adapt to the changing environment. This, in turn, allows mobile robots to be used also for monitoring and inspection of production facilities and infrastructure. They can patrol the factory site, detecting early signs of malfunctions or improper operation of machinery, which allows for quick response and minimization of production downtime. It can therefore be concluded that mobile robots play one of the key roles in the production process in Industry 4.0.

The education process and Industry 4.0

The production system in Industry 4.0 is very complex, but it offers very great opportunities related to monitoring, supervision and making production more flexible. As the level of technological production increases, well-educated personnel at both the production and maintenance managerial levels are also essential. So a modern education system must respond to these demands. At present, it is not possible to educate a single versatile worker who is capable of doing both production and maintenance work. While training an employee in one part of an integrated production system is possible (e.g., in production or information flow), retraining an employee between different parts, e.g., from the production system to the logistics part is already very difficult, and training is expensive and time-consuming. Thus, it is necessary to train employees in a specific field, e.g. machine tool operation, integration of information flow systems, or logistics. An important aspect is the amount of knowledge and soft skills that employees must acquire. Nowadays, the scope is getting wider and wider. Therefore, the start of training in a specialization should begin as early as high school, where students are introduced to the operation of equipment and, as technicians, can begin work that requires the lowest qualifications. Subsequently, in college, the range of competencies should be expanded, with competencies related to higher levels of Bloom's taxonomy such as analyzing, evaluating and creating. These employees are predisposed to design and create advanced manufacturing technologies in the field of Industry 4.0. It should be further emphasized that in modern systems, teams of people who are specialists in their field, e.g. sensory systems, programming, data transmission systems, material processing, management and artificial intelligence, work on the development of a given technology. Of course, it should be noted here that today some technologies are purchased from specialized companies, e.g. communication systems, e.g. EtherNET, EtherCAT, ProfiBus, or ProfiNET, PLC systems, e.g. Mitsubishi, Siemens, or FATEC, or sensory or logistics systems - mobile vehicles. On the other hand, integrating them into a single system related to Industry 4.0 is time-consuming and very difficult without the right competence.

It should be noted here that modern laboratory facilities play an important role in the process of training employees. The use of modern laboratories and industrial simulations allows for the practical training of workers in a realistic environment, making it possible to apply theory to practice. Vocational training should also promote an interdisciplinary approach, integrating technical sciences, information technology, as well as interpersonal and management skills, without abandoning the acquisition of specific knowledge in a particular specialty.

Thus, the answer to the question of what kind of profile a technical school or college graduate should have is not clear-cut, because the sought-after ideal profile for different companies and their requirements does not exist, and rather, technological progress forces one to deepen one's competence in a specific direction, rather than acquiring residual knowledge in many directions. On the other hand, in the process of integrating multiple systems in Industry 4.0, an employee needs to know the basics in various fields to be able to safely perform his duties with the production process. On the other hand, a good school or university, in order to meet the expectations of the market, educates pupils or students in a wide range of competencies leaving out the deepening of competence in a particular field. Thus, it can be concluded that the expectations of employers and schools and universities are becoming increasingly divergent.

The conclusion of such a state of affairs is one. The educational process focuses on broad education, showing specific issues to students and pupils, while detailed knowledge and "deeper" specialization are acquired through additional courses and training. These, in turn, are often accomplished by sending the newly hired employee to companies that specialize in training or directly to companies that sell specific equipment such as robots, data network controllers, artificial intelligence.

It should still be noted that there are specific fields of study in both technical schools and universities. Back in the 1990s and the beginning of the current century, the division into majors was sufficient to keep up with market expectations. In contrast, today even the introduction of specializations in the given fields of study is insufficient. Therefore, specialized training centers are now being created, which are equipped with state-of-the-art equipment, and which employ specialists in a particular field to conduct specific courses and training. This approach to training is called micro-competence education. It is associated with "in-depth" training of usually several days in a specific area of competence. This type of training fills the gap between the profile of the graduate and market expectations. The disadvantage is the high cost of such courses, which must be covered by the graduates themselves or the employer.

Automation and Robotics in Industry 4.0

Automation and robotics play a key role in the context of Industry 4.0, which is a new era of industrial revolution based on advanced digital technologies. Industry 4.0 combines traditional manufacturing processes with modern information technologies, leading to a more efficient, automated and flexible manufacturing environment. Here are some key aspects of Automation and Robotics in Industry 4.0.

Integrated Automation Systems

In Industry 4.0, automation systems are integrated with information systems, enabling better synchronization and management of production processes. Automation includes not only production, but also logistics, quality control and other areas.

Integrated Automation Systems are comprehensive solutions in which the various components of a production system, such as machines, equipment, robots, software, sensors and control systems, are closely synchronized and work together. The goal is to achieve maximum efficiency, flexibility and responsiveness to changing conditions.

Integrated Automation Systems integrate the different layers of production, combining the operational (OT - Operational Technology) and information (IT - Information Technology) levels. As a result, information from production lines can be easily accessed by business management systems.

Integrated Automation Systems rely on effective communication between different devices in a factory. Communication standards such as OPC UA (Unified Architecture) are widely used, enabling interoperability between different manufacturers and types of equipment.

Control of production processes is done centrally, allowing monitoring and control from a single location. Centralized control allows rapid response to changes in conditions, minimizing the risk of errors and increasing efficiency. Integrated Automation Systems enable the cooperation of different systems, such as MES (Manufacturing Execution System), ERP (Enterprise Resource Planning) or PLM (Product Lifecycle Management), allowing optimal production management at different levels. Thanks to their integration, production systems can be quickly reconfigured in response to changing market conditions, changing product demand, or technological innovations.

Integrated Automation Systems enable the use of advanced data analysis algorithms and artificial intelligence to make real-time decisions. This enables process optimization and identification of areas of improvement.

Integrating manufacturing systems with supply chain and customer relationship management systems enables more efficient production planning, adaptation to changing demand and faster delivery of products.

Integrated Automation Systems are the foundation for Industry 4.0, enabling companies to achieve more efficient, flexible and agile manufacturing processes. As a result, companies are able to respond better to dynamic market changes, increasing their competitiveness.

Using Industrial Robots

Industrial robots play a key role in automated production lines. They are used to perform a variety of tasks, from simple and repetitive to more complex and precise operations.

The use of Industrial Robots is a key element of Industry 4.0, bringing advanced and intelligent automation solutions to manufacturing processes. Industrial Robots in Industry 4.0 are not just physical machines, but intelligent systems capable of collaboration, adaptation to change and integration with other technologies. Below there is a description of the use of Industrial Robots in the context of Industry 4.0:

Automated Production Lines

Industrial robots are used to automate various stages of production, covering assembly, handling, welding, packaging and other tasks. This increases production efficiency and eliminates monotonous tasks.

Human-Robot Collaboration

In Industry 4.0, industrial robots often work on the same jobs as humans. Collaborative robots are designed to work safely with workers, making efficient use of both human and machine skills.

Artificial Intelligence in Robotics

Industrial robots use artificial intelligence technologies such as machine learning to adapt to changing conditions, analyze data and make real-time decisions.

Mobile Robots

Industry 4.0 uses mobile robots capable of moving around the factory and performing various tasks. These robots are equipped with sensors, cameras and navigation systems, allowing them to adapt to changing environments.

Internet of Things (IoT) in Robotics

Industrial robots are being integrated with the IoT, enabling the collection of performance, condition and energy consumption data. This information is used for analysis, maintenance planning and process optimization.

Advanced Motion Control

Industrial robots in Industry 4.0 use advanced motion control algorithms to perform tasks in a precise and coordinated manner. They can respond to changing environmental conditions and adjust their movements.

Programmability and Flexibility

Robots in Industry 4.0 are programmable and flexible, allowing them to quickly adapt to different tasks and products. The use of offline programming and plug-and-produce technology enables rapid deployment and modification of robot tasks.

Remote monitoring and diagnostics

Industrial robots are capable of remotely monitoring their condition and transmitting data on failures or maintenance needs. This makes it possible to respond quickly to potential problems and minimize downtime.

Optimizing Energy Consumption

In Industry 4.0, robots are designed with energy efficiency in mind. Monitoring energy consumption allows optimization and reduction of operating costs.

Using Industrial Robots in Industry 4.0 contributes to the efficiency, flexibility and intelligence of manufacturing processes. The integration of robots with advanced technologies makes them not only a tool for performing tasks, but also intelligent partners in the production process.

Intelligent Control Systems

Automation in Industry 4.0 relies on intelligent control systems that use advanced algorithms and artificial intelligence to optimize production processes, monitor and diagnose defects. Intelligent Control Systems (ISCs) are a key component of Industry 4.0, aimed at effectively managing, monitoring and optimizing manufacturing processes. These systems use advanced technologies such as artificial intelligence, data analytics and predictive algorithms to enable dynamic control of processes in real time.

Internet of Things (IoT)

Automation in Industry 4.0 works closely with the Internet of Things. Machines, equipment and robots are connected, enabling real-time data collection and remote monitoring and management of production.

The Internet of Things (IoT) in industry is the use of communication and sensor technologies to connect various devices, machines, systems and people together to effectively monitor, manage and optimize production processes. IoT in industry aims to create a more integrated, intelligent and flexible manufacturing environment. Here are some key aspects related to the use of the Internet of Things in industry:

Real-Time Data Collection

Sensor-equipped equipment collects data on machine status, temperature, energy consumption, as well as other production parameters. This data is collected in real time, enabling rapid response to changing conditions.

Integration of Systems

IoT integrates various manufacturing systems, such as automation systems, production management systems, Enterprise Resource Planning (ERP) systems and others, creating a cohesive and integrated environment. This allows efficient management of processes at different levels of the company.

Automation and Control at a Distance

With IoT, machinery and equipment can be remotely monitored, controlled and maintained. This makes it possible to remotely manage production and quickly respond to any failures or problems.

Sensors for Quality Monitoring

IoT sensors are used to monitor product quality in real time. This allows quick detection of production defects and taking immediate corrective action.

Energy Consumption Optimization

IoT enables real-time monitoring of energy consumption to identify areas where energy can be saved and implement energy optimization in production processes.

Real-Time Supply Chain

The use of IoT allows for real-time tracking and management of the supply chain. Access to real-time data on inventory, production or transportation increases the efficiency of supply chain management.

Security and Monitoring

IoT assists in monitoring workplace safety, both by remotely monitoring environmental conditions and tracking employee movement. This contributes to improved working conditions and safety.

Rapid Diagnostics and Maintenance

By continuously monitoring the condition of equipment, IoT enables rapid diagnosis of potential failures. This allows maintenance to be scheduled before scheduled production shutdowns.

Artificial Intelligence in Data Analysis

Using artificial intelligence to analyze data collected by the IoT allows you to detect patterns, predict failures, and adjust processes in real time.

Manufacturing Flexibility

Through the use of automation and robotics, Industry 4.0 is characterized by greater manufacturing flexibility. Systems are more adaptable to changes in demand, and changes in production configuration can be made quickly and efficiently.

Digital Supply Chain Integration

Automation and robotics integrate with digital supply chain management systems, enabling better production planning, material tracking, and rapid response to changing market conditions.

Robot Safety and Ethics

In Industry 4.0, where robots play a key role, issues related to robot safety and ethics are becoming increasingly important. Standards and procedures are being developed to ensure the safe use of advanced automation systems.

As a result, Industry 4.0 relies on more integrated, intelligent and flexible manufacturing systems that allow companies to respond quickly to market changes, minimize waste and increase production efficiency. Automation and robotics are key elements in this transformation.

Big Data in Automation

In Industry 4.0, automation systems generate huge amounts of data. The use of data analytics (Big Data) allows for better understanding of production processes, predicting machine failures, and optimizing productivity.

Artificial Intelligence (AI) in Robotics

The integration of artificial intelligence with robotics allows the development of more advanced robot functions, such as machine learning, pattern recognition and self-learning capabilities. This contributes to the adaptability of manufacturing systems.

Artificial Intelligence (AI) in industrial robotics is an area where advanced artificial intelligence technologies are used to provide robots with the ability to learn autonomously, adapt to changing environmental conditions and make intelligent decisions in real time. In Industry 4.0, the integration of AI with robotics allows robots to develop more advanced functions and applications. Here are some key aspects related to the use of AI in Robotics in the context of Industry 4.0:

Machine Learning

Machine learning algorithms allow industrial robots to analyze data, identify patterns and adjust their behavior based on experience. This enables robots to adapt to changing production conditions.

Pattern and Object Recognition

With AI, robots are capable of recognizing patterns and objects in their environment. They can identify products, tools or parts on a production belt, which is crucial for precise and sustainable manufacturing processes.

Machine Learning in Motion Optimization

Artificial intelligence is being used to optimize robot motion trajectories. Industrial robots, using machine learning algorithms, can adjust their movements, minimize downtime and increase precision.

Autonomous Decision Systems

Artificial intelligence enables industrial robots to make decisions based on real-time data analysis.

Adaptive Robot Programming

Thanks to AI, industrial robots can be more flexible in terms of programming. They can learn new tasks, adapt to changes in the manufacturing process and respond quickly to new challenges.

Developed Vision Systems

AI supports the development of advanced vision systems in robots. Robots are capable of recognizing workpieces, identifying quality products, and detecting potential problems on the production line.

Predictive Diagnostics and Maintenance

AI is used for predictive diagnostics and maintenance of robots. By analyzing data collected by sensors, industrial robots can predict potential failures and schedule maintenance before problems occur. It is also possible to select a time for technical inspections and maintenance when downtime will be least problematic for the production process.

Artificial Intelligence in Industrial Robotics in Industry 4.0 not only increases the autonomy of robots, but also introduces a more adaptive, precise and intelligent approach to production automation. This allows for more efficient use of resources, increased production flexibility and improved product quality.

Wearable Technologies in Industry 4.0

Wearable robots (robots) are becoming increasingly common in industry, assisting workers in performing physically demanding tasks. These technologies have the potential to improve work ergonomics and increase productivity.

Industrial wearable technologies play an important role in improving efficiency, safety and communication in the workplace. These innovative wearable devices enable employees to track data, monitor health and provide real-time access to information. Below there is a description of wearable technologies in the context of Industry 4.0:

Smart Glasses

Smart glasses are worn by workers and equipped with a screen that displays information in the wearer's field of vision. In industry, they can be used to provide work instructions, design, machine operation, and to transmit information on production status.

Smart Helmets

Smart helmets are helmets equipped with advanced features such as cameras, microphones, headphones and even augmented reality (AR) systems. They are used to give workers access to information and visualize data in real time.

Wearable Sensors

Wearable sensors on a worker's body collect data related to movement, body position, and physiological parameters such as heart rate and temperature. This data can be used to monitor work performance, track employee health, and improve workplace ergonomics.

Exoskeletons

Exoskeletons are worn on the body and support workers' physical tasks by enhancing physical strength or reducing strain. In industry, they can be used to help lift heavy objects or protect workers from injury.

Wearable Communication Devices

Wearable communication devices, such as smart watches and special communicators, make it easier for employees to communicate in real time. This, in turn, improves team coordination, responsiveness to change and enhances safety.

Wearable Barcode Scanners

Warehouse or logistics workers can use wearable barcode scanners to quickly scan products or materials, speeding up order picking processes, inventory control and shipment tracking.

Wearable Biometric Devices

Wearable biometric devices, such as bracelets or rings, can monitor employees' physiological parameters, such as heart rate, temperature and stress levels. This information can be used to protect against overexertion or accidents.

Wearable Tracking Devices

Wearable location-tracking devices, such as GPS in smartwatches or special tags, allow monitoring the movement of workers in the workplace. This can be used to optimize routes, increase security or manage access.

Wearable Health Monitoring Devices

Health monitoring devices worn by employees allow them to track health parameters such as activity levels, sleep and step count. This promotes health promotion and prevention of work-related diseases.

Industrial wearable technologies allow the introduction of more integrated, efficient and safe work processes. They enable employees to use advanced technologies without interrupting their activities, which contributes to improving overall productivity and comfort at work.

Autonomous Manufacturing Systems

Autonomous manufacturing systems that are capable of autonomously managing and optimizing production processes are being constantly developed. These systems are able to adapt to changes in the production environment without the need for human intervention.

Autonomous Production Systems are advanced industrial solutions that are capable of autonomously managing and controlling production processes without human supervision. These systems are an integral part of the Industry 4.0 concept, and are designed to make production more efficient, flexible and adaptive. The following are the main features and components of Autonomous Manufacturing Systems:

Autonomous Decisions

Autonomous Manufacturing Systems have the ability to make decisions without human intervention. They use a variety of data from sensors and monitoring systems to analyze situations and make real-time decisions.

Adaptability to Change

These systems are flexible and adaptive, able to adjust to changing production conditions, changing customer demands or equipment failures. They strive to optimize processes according to current conditions.

Integrated Communication Systems

Autonomous Manufacturing Systems are based on highly integrated communication systems. This allows the various components of the system to work together, exchanging information and coordinating their activities.

Machine Learning and Artificial Intelligence

They use machine learning and artificial intelligence technologies to analyze data, identify patterns, predict failures and adapt to changing conditions. This enables the system to continually improve its skills.

Autonomous Motion Control

Manufacturing systems are capable of autonomously controlling the movement of machines, robots and other parts of the production line. Autonomous control includes trajectory optimization, speed control, and collision avoidance.

Applications of Collaborative Robots

Autonomous Manufacturing Systems use collaborative robots that can work effectively with humans. These robots are capable of performing tasks together, which increases production flexibility.

Condition Monitoring

These systems are equipped with sensors that monitor the technical condition of machinery and equipment. As a result, they are able to predict potential failures and schedule maintenance, minimizing production downtime.

Distributed Control Systems

Autonomous Manufacturing Systems are based on distributed control systems, which means that different components of the system have autonomy in decision-making. This provides flexibility and scalability to the system.

Cyber-Physical Security

Cyber-physical security is a priority in Autonomous Manufacturing Systems. This includes safeguards against cyber-attacks, but also attention to the physical safety of employees.

Vision Systems and Virtual Reality

These systems use advanced vision systems and virtual reality to monitor processes, visualize data and train workers.

Autonomous Manufacturing Systems represent an advanced stage in the evolution of industry, moving toward automation, intelligence and flexibility. Their implementation aims to increase productivity, reduce costs and increase the competitiveness of manufacturing companies.

Vocational Training and Industrial Competence

Due to the rapid development of technology in industry, there is a growing demand for workers with modern competencies in automation, robotics, programming, data analysis and management of industrial systems.

Vocational education and the development of industrial competencies play a key role in the context of a dynamically changing work environment, especially in the era of Industry 4.0. Vocational education aims to prepare employees to function successfully in modern industry, requiring advanced technical, interpersonal and analytical skills. Here are some key aspects related to vocational education and industrial competencies:

Training programs aligned with Industry 4.0

Vocational training should include programs tailored to the requirements of Industry 4.0, taking into account the latest technologies such as artificial intelligence, automation, the Internet of Things, and cyber-physical manufacturing systems.

Industrial Laboratories and Simulations

The use of state-of-the-art industrial laboratories and simulations allows for hands-on training of employees in a realistic environment, enabling the application of theory to practice.

Integrated Interdisciplinary Courses

Vocational training should promote an interdisciplinary approach, integrating technical sciences, information technology, as well as interpersonal and management skills.

Apprenticeships and Internships

Allowing apprenticeships and internships in industrial companies enables students to gain practical experience, as well as establish contacts in the industry.

Alignment of Programs to Labor Market Needs

Vocational training programs should be flexible and regularly adapted to the changing needs of the labor market in order to fully respond to current industrial challenges.

All in all, Automation and Robotics in Industry 4.0 is a vast area that encompasses many advanced technologies. The implementation of these solutions contributes to the transformation of traditional manufacturing models, enabling more sustainable, intelligent and flexible production.

Summary

Technological development is trying to keep up with the ever-increasing demands of consumers, which are increasingly individualized. This entails making the production system more flexible. On the other hand, constant competition with other companies requires cost reduction in order to lower the price of the product. Accordingly, automation integrated with diagnostic, information and decision-making processes based on artificial intelligence issues is being introduced into production. The more complex the system, the greater the need for employees with narrow but highly detailed competencies. This, in turn, translates into the need for a large number of employees with detailed competencies in various fields.

The next Industrial Revolution 4.0 introduces mass production in an automated manner, which translates into a reduction in employment in the production process itself, but requires the hiring of a much better and more detailed trained workforce.