SYSTEM OF DESIGNING ROBOTIC WORKPLACE

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Abstract

Developments in the field of computing simulation bring new research opportunities for the field of logistics as well. The Industry 4.0 concepts and trends also brought a new topic which focus on the design of robotic workplace in particular manufacturing halls or companies. The form of the method of designing production workplaces has changed significantly over the last decade, affecting both the logistics and the tools and procedures used in the design. The development of computer visualization tools enables the implementation of virtual production before the first product is even produced. For this reason, the method and procedures of designing production workplaces were changed and reoriented to a visualization form. The paper deals with the development and procedures of designing a production workplace with the help of modern systems.

Keywords: Robotic workplace, system of designing, simulation, Industry 4.0, Industry 5.0

1. INTRODUCTION

The fourth industrial revolution was first mentioned in 2011, and more than a decade later the European Commission announced the beginning of the Industry 5.0 era. While Industry 4.0 is characterized by the use of CPS (cyber-physical systems) and smart factory concepts, and often automation at various levels, Industry 5.0 already represents a collaboration between automation and human factor that is at the forefront and is designed to support companies to not only achieve global goals, to minimize costs and maximize profits, but also social goals more effectively [1] „Industry 5.0 is the recognition of industry’s ability to achieve social goals beyond employment and growth, and to become a resilient source of prosperity by making production respect the boundaries of our planet and putting the well-being of industrial workers at its core production processes [1,2]. Therefore, the goals of the Fifth Industrial Revolution represent the well-being of people at the core of the production system, so that companies and humanity will be able to achieve social goals and sustainable development that go beyond employment and growth to ensure prosperity of whole society. However, it is necessary to note, that the current research on Industry 5.0 is still in its infancy, with relatively few research results which are not very systematic [3]. As we already mentioned, the main interest of Industry 4.0 is automation, but with Industry 5.0, the human element is reintroduced into the production space as it is believed that this integration will bring the creativity and intelligence of humans and machines into the production facilities of the future. We call this collaboration HRC (Human-Robot Collaboration) [4]. As a result, businesses should experience an increase in the efficiency of their production processes, leading to some added value, prosperity and cost reduction. Today, HRC is considered one of a wide and diverse set of research and other activities, as this integration drives us towards a hybrid combination of production plants, companies or factories [5]. But it is important to note that not many workplaces currently offer effective collaboration. Therefore, the design of the robot used and its placement play a very important role from an efficiency point of view and especially from a safety point of view. Therefore, the issue of designing collaborative robots is important as safety and ergonomic aspects are relevant to manufacturing production [6]. Today's trends not only indicate increasing global competition, with customer satisfaction being a top priority, but their requirements are also constantly changing, resulting in the need for companies to become more flexible and efficient [7]. For these reasons, we can consider collaboration between humans and robots as one of the key factors that represents a prerequisite for the future of variable, flexible and efficient production [8].

2. METHODOLOGY

As with all new innovations and technologies, the development and integration of human and robotic agents is advancing. Research in this area mainly focuses on human safety, the level of collaboration between robots and humans, and the level of autonomy and adaptability of the robot itself. We can look at it from multiple angles to determine different types of robots tasks and activities. The aim of this collaboration is to find smooth team dynamics and communication fluidity in purely human teams, which also falls under the HRC collaboration. In the past, industrial robots were traditionally precisely fixed and programmed based on the principles of high speed and high torque, and only replaced human factors in production and other operations. Rather, HRC is based on the fact that robots somehow support and facilitate people's work. In the industrial sector, HRC combines the requirements of these two elements when building intelligent robots and cobots ensuring that they are not only aware of their environment, but also of their human partners in production [8].

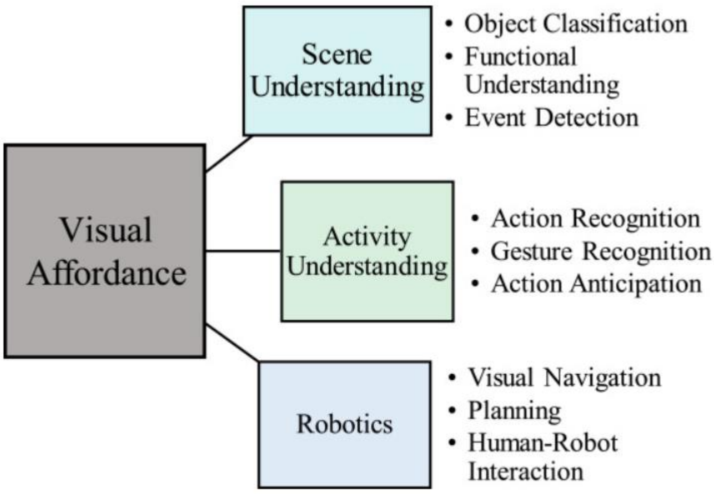

Figure 1 HRC understanding, activity and robot control [8]

2.1 Robots and its types

A robot is a specific machine equipped with sensors, control instruments, support devices and a certain (and in some cases even limited) level of artificial intelligence, usually capable of performing tasks associated with a specific type of work [9]. Robots come in many shapes and designs, with more or less flexibility and functional autonomy in performing tasks [10]. In practice, what we initially found were pre-programmed robots, such as those used in car manufacturers' assembly shops. These are designed to perform tasks described in a precisely defined and controlled environment. We also recognize remote-controlled robots that are continuously controlled by a remote operator. The best and most typical examples of this type are drones, robotic submarines and robots used in surgeries. We will also encounter autonomous robots that are already able to sense their environment and act in a targeted manner. One example is a delivery robot in a hospital that dispenses and registers medications for patients. At the same time, in practice we may also encounter an "extended" robot, which represents a connection or integration with the human body. As an example we can cite exoskeletons that can be used by (partially) paralyzed people, for example for walking or robotic legs or arms. Every type of robot has entered the market, the workplace, or daily life [11].

3. STATE OF ART

Designing HRC workplaces is challenging, especially given the complexity of humans and the variety of possible interactions that can occur during production. As part of HRC research, we can address a variety of application methods, including humanoid robots, vehicle navigation, rescue robots, assistive robots, and collaborative robots [16]. The integration of robots with human operators is based on market pressure to increase efficiency, flexibility and productivity. To some extent, there is also a need to reduce people's workload and stress. Today, this is possible thanks to the integration of robots into production processes. The mentioned interactive systems are divided into two types, in which the work area is shared or partially shared for a certain period of time, depending of course on the functionality of the individual robots. In both cases, humans act as operators, while robots only undertake individual collaborative tasks. The arrangement or layout of robotic workstations allows human operators to play multiple roles in the production process, such as supervisor, operator, co-worker, machinist, repairman, programmer, or even just a regular passerby. From the degree of interaction itself, we can further divide HRC systems into the following types:

- robots and human operators share a common space as they are connected by common tasks,
- robots and humans have an independent working relationship, that is, each has an independent work area and tasks are divided between the two [15].

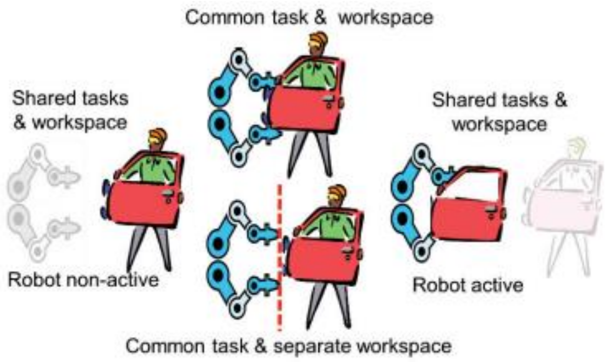

Figure 2 HRC tasks and workspace [15]

3.1 HRC and collaborative workplace design

The successful introduction of HRC depends largely on the reliability of the robot, in this sense reliability is understood as the ability to provide a trustworthy service. However, reliability is a focused concept consisting of attributes such as safety, availability, predictability, integrity, and sustainability. It has been mentioned many times, but security is a key aspect. The main characteristics are the subjective state of the system user and the objective characteristics of the system itself. Although there are no errors in the system, it cannot be said with certainty that the system will not have conflicts or errors. It plays out in everyday life where we have to assume that something might happen because we can't completely rule out some form of danger. Therefore, planning and designing production processes in a robotic workplace is a challenge, but very beneficial to the business itself. Designing reliable systems is based on experience, knowledge and technical skills, allowing us to design optimal solutions. In part, this requires careful choices of system architecture and mechanisms, as well as technologies and technical practices. Until recently, the use of robotic assistants was made more difficult by a lack of reliable standards and technology to ensure safe operation. Operating an HRC, especially in a shared environment, is a complex issue that requires a comprehensive assessment of multiple criteria. The design and presentation of optimal layout solutions is a central aspect when integrating HRC into the production process. The ultimate, optimal and efficient workplace design must ensure minimal movement, transition times and paths, as well as maximize resource utilization and ensure workplace safety.

A given location of a resource is related to delivery time, productivity, and total cost [5]. Guidelines and laws have been introduced within the framework of national and international standards, allowing us to easily integrate system security. The reality is that a shared workplace, whether it's people, robots or assistive equipment, that is, every location, brings with it unique risks that can arise. There are currently 30 EU directives in force and 600 different safety standards. Robotic workstations and the cells in which robots are located require multiple strategies to achieve safety. When planning and designing a robotic workplace, the following factors must be considered from a safety perspective:

1. **Safety-related control system** performance must tolerate single faults without compromising safety.
2. Every robot must have protective and independent **emergency stop**.
3. **Speed control** is essential, with collaborative robots not exceeding 250 mm/s in their tool center point (TPC) speed.
4. Collaborative robots should provide visual indications for **collaborative operation** and meet specific requirements, including safety-rated monitored stops, hand guiding with speed monitoring, and power and force limiting.
5. **Limiting robot motions** can be achieved through integral systems, external devices, or dynamic limiting without control devices.
6. Minimum separation **distance between robots and operators** depend on risk assessments, considering hazards, workspace layout, tasks, and usability.
7. **Collision detection** and avoidance functions help prevent collisions by slowing down, reversing, or following a safer path.
8. **Technological and ergonomic requirements** ensure contact areas are safe, with no sharp or rough edges, and the working space provides ample room to avoid clamping situations.

4. DISCUSSION

Title by Michalos et. al (2015) [15] discussed the issue about investigation of different HRC schemes related to safety aspects that need to be considered during the process of designing robotic workplace. In the case of Automotive rear suspension assembly, a high payload robot assist a human worker in the loading of axles and rear wheel groups. The robot handles the loading of axles, while for the rear wheel groups, a collaborative effort is employed. The robot picks up the wheel groups and positions them relative to the axle, and the human worker manually aligns the parts with the screw holes. The heaviest item the human handles is a screwdriver. As the human worker completes delicate tasks, the robot continues bringing the second wheel group without colliding with the human. The human can guide the robot through gestures or audio commands, actively fine-tuning the part positioning by hand. Safety measures include the use of virtual volumes for manual guidance, and a Safety Eye system to adjust the robot's speed or stop its motion when the human is nearby, ensuring safety during the process [15].

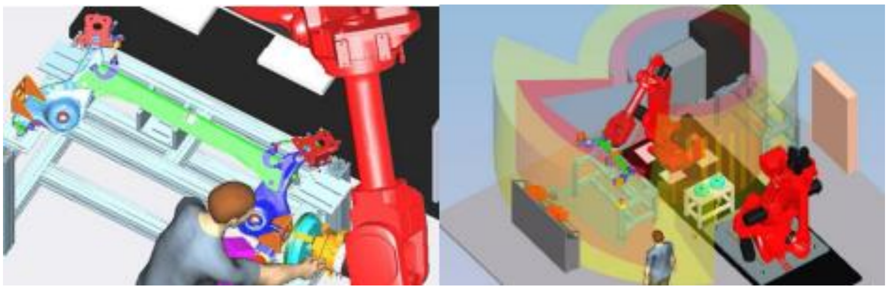

Figure 3 HRC assembly and Safety Eye sensor [15]

The second scenario discussed Automotive dashboard preassembly. This scenario involves automating the assembly of components in vehicle's dashboard. Initially, a human worker loads a longitudinal component called the traverse onto a station and installs various parts, including a body computer and a cable. In a hybrid solution, a COMAU Dual-Arm Robot assumes responsibility for loading and assembling tasks, such as placing a body computer and screwing it in place, and cooperates with a human worker to install a cable. Safety is a top priority, with a PILZ Safety Eye camera featuring detection and warning zones employed to ensure the safety of both the human and the robot. The robot can halt its movement when the human enters the warning zone, allowing collaboration in designated areas while maintaining safety. In summary, the choice of equipment and layout in various scenarios is influenced by specific factors. Fenceless separation monitoring demands substantial space between human and robots for the supervision system to be effective. In contrast, close collaboration requires less physical separation, but necessitates advanced collision detection and avoidance capabilities. Future efforts should explore methods like augmented reality for enhancing human understanding of safety measures [15].

5. CONCLUSION

Future efforts should explore methods like augmented reality for enhancing human understanding of safety measures [15]. Virtual reality and simulation of the robotic workplace can undoubtedly be considered an important technology with the potential to be used at different levels of industry and in all types of environments. This combination avoids all possible mistakes and collisions and, above all, does not require an initial, often high investment, and no one is exposed to high dangerous risks. In this way, misunderstandings, errors or conflicts can be avoided, while time and costs are reduced, resulting in the best possible solution.

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