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Editorial

Industrial Process Improvement by Automation and Robotics

Raul D. S. G. Campilho [1,2,*] and Francisco J. G. Silva [1,2]

[1] ISEP—School of Engineering, Polytechnic of Porto, R. Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal; fgs@isep.ipp.pt
[2] INEGI—Institute of Science and Innovation in Mechanical and Industrial Engineering, Pólo FEUP, Rua Dr. Roberto Frias, 400, 4200-465 Porto, Portugal
* Correspondence: rds@isep.ipp.pt; Tel.: +351-939-526-892

Automation and robotics have revolutionized industrial processes, making them more efficient, precise, and flexible. The integration of automation and robotics into manufacturing and production has been a pivotal driver of industrial advancements [1,2]. The ability to improve quality, reduce human error, and increase production speed has made these concepts indispensable for various industries [3]. Moreover, automation and robotics are becoming particularly relevant in the era of Industry 4.0, where smart manufacturing and mechatronics play a crucial role [4]. In this Editorial, the state of the art in automation and robotics, their applications, current limitations, and future perspectives within the context of improvements in the industrial process are explored.

Automation involves the use of various control/sensor systems and actuators to operate machinery, reducing the need for human intervention [5]. Automation can be as simple as a thermostat regulating room temperature or as complex as a fully automated assembly line [6]. The primary goal is to enhance efficiency and productivity while minimizing errors [7]. This approach has found its place in a variety of industries, with the automotive sector emerging as a major catalyst for the advancement of automation systems, driven by the pursuit of heightened productivity and enhanced flexibility [8,9]. Groover [10] outlines several key factors that prompt businesses to embrace process automation, including increased productivity, reduced production costs, improved part quality, shorter delivery times, the execution of tasks that are impractical for manual labor, the prevention of non-automation-related expenses, and the reduction in or elimination of manual operations. Moreover, automation enables line operators to transition to a more supervisory role, relieving them of monotonous, repetitive, and labor-intensive work, while simultaneously ensuring the company's competitiveness [11]. One of the most significant advancements in automation is the implementation in the principles of Industry 4.0. Industry 4.0 represents the fourth industrial revolution and is characterized by the integration of digital technologies into industrial processes [12]. This concept includes the use of the Internet of Things (IoT), artificial intelligence (AI), and big data analytics. In Industry 4.0, machines communicate and make decisions independently, leading to what is often referred to as the "smart factory" [13]. This principle results in enhanced efficiency and productivity and reduced downtime by the application of predictive maintenance supported on data analytics, machine learning, and the IoT [14]. Automation and Industry 4.0 have allowed for more efficient production, quicker decision making, and improved resource allocation. With real-time data analysis and optimization, companies can minimize waste, reduce energy consumption, and increase the quality of their products [15].

Robotics goes beyond automation by introducing physical machines that can perform tasks with a high degree of autonomy. These machines are equipped with sensor and actuator systems that enable them to interact with their environment [16]. Robotics plays a significant role in flexible production, particularly when tasks require precision and adaptability [17]. Robotics has become increasingly prevalent across diverse industrial applications [18,19]. While various definitions of robots exist, the ISO 8373 standard

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characterizes a robot as a reprogrammable and multifunctional manipulator, controlled in position, with one or multiple degrees of freedom, capable of manipulating objects using programmed movements to execute various functions [20]. Industrial robots typically comprise three key components: the manipulator (robot), a controller, and a user interface (programming console). The robot is equipped with sensors and actuators, which are the senses and muscles of robotic systems. Sensors provide data about the robot's surroundings, including information about temperature, humidity, light, and object detection [21]. Actuators are responsible for converting digital instructions into physical movement. Advances in sensor technology, such as Light Detection and Ranging (LiDAR), cameras, and ultrasonic sensors, have improved robots' ability to navigate and interact with their environment [22,23]. Similarly, actuator advancements, like advanced servo motors, enable robots to perform tasks with greater accuracy and agility [24]. The integration of sensor and actuator technologies has had a profound impact on the field of robotics. Robots are now capable of performing complex tasks like pick-and-place operations, assembly, and even intricate surgical procedures [25]. They can work alongside humans in collaborative settings, which is particularly beneficial in manufacturing environments [26]. Presently, industrial robots play a pivotal role in automotive production lines, with the application of robots in this industry gaining substantial traction in recent years. This move toward robotization facilitates the assembly of different vehicles on a shared production line, resulting in reduced production costs for small- and medium-scale operations compared to dedicated automation or manual labor-based assembly lines [16,27]. The primary drivers for integrating robots in industries are the need to operate in hazardous environments, the execution of repetitive tasks, the management of intricate handling processes, and the maintenance of continuous operation [28,29]. The current state of the art in robot development, which includes control systems and sensor technologies, ensures the safe utilization of these systems in production and assembly lines [30,31], and this safety extends to collaborative operations, combining the productivity attributes of robots with the improved cognitive and decision-making skills of human operators, thereby enhancing overall manufacturing and assembly efficiency [32].

Currently, the applications of automation and robotics are widespread in industry and society in general. The most prominent applications are as follows:

- Manufacturing: One of the primary applications of automation and robotics is in manufacturing. Automated assembly lines have become the main assurance of companies' competitiveness [33,34], producing a wide range of products, from consumer electronics to automobiles. Robots can handle repetitive and hazardous tasks with precision and consistency. Their application ensures that defects are minimized, resulting in higher-quality products [35].
- Healthcare: In the healthcare sector, robotics has seen major advances. Robotic surgery, for instance, has become more common, allowing for minimally invasive procedures to be performed with high precision [36]. Robots can also assist in patient care, such as in the delivery of medications or in the rehabilitation of patients [37].
- Logistics and warehousing: E-commerce and the demand for rapid order fulfillment have led to the adoption of robotics in logistics and warehousing. Automated guided vehicles (AGVs) and drones are used for material handling and order picking. This procedure speeds up the process and reduces the risk of errors in inventory management [38].
- Agriculture: Robots are used for tasks like planting, harvesting, and monitoring crops. These machines can work uninterruptedly, improving the efficiency of farming operations [39]. The integration of automation and robotics in agriculture is essential to meet the growing global food demand [40].
- Service and entertainment: Robotic technology has also found its way into the service and entertainment industries. Robots are used as receptionists, guides in museums, and even as companions for the elderly [41]. Entertainment robots, like those used

in theme parks, enhance visitor experiences and provide a unique form of entertainment [42].

Despite the major advances and breakthroughs in automation and robotics, which has led to the most diverse applications, as described, limitations persist related to these technologies that need to be addressed, such as:

- High initial investment: The initial cost of implementing automation and robotics systems can be substantial. Small- and medium-sized enterprises (SMEs) may find it challenging to invest in this technology, hindering its widespread adoption [43].
- Complexity and integration: Integrating automation and robotics into existing systems can be complex. It requires a deep understanding of the specific needs of the industry and often involves custom solutions. This complexity can be a barrier for many businesses [44].
- Workforce disruption: The fear of job displacement remains a concern. While automation and robotics can improve efficiency and productivity, they may also lead to job displacement. It is crucial to manage this transition by upskilling the workforce and focusing on roles that complement automation rather than firing the line operators that previously accomplished the repetitive tasks [11].
- Safety: Ensuring the safety of workers and humans when robots operate in shared spaces is of utmost importance. Safety standards and risk assessment procedures must be in place to prevent accidents and injuries [45].
- Lack of standardization: The lack of standardized interfaces and communication protocols can hinder the interoperability of different automation and robotics systems [46]. Standardization efforts are ongoing, but more progress is needed to achieve seamless integration [47].

As technology and scientific knowledge continue to evolve, the future of automation and robotics holds promising opportunities and prospects for future research:

- Human–robot collaboration: Collaborative robots, or "cobots," are becoming increasingly applied on the factory floor. These robots work alongside humans, enhancing productivity in complex tasks [48]. Future developments in this area will focus on improving the ease of programming and the flexibility of these systems [49].
- AI and machine learning: Advancements in AI and machine learning will lead to more intelligent and adaptable robots that will be capable of learning from their experiences and continuously improving their performance [50].
- Interconnected systems: The integration of robotics and automation with Industry 4.0 principles will lead to more interconnected systems [51], leading to higher efficiency and productivity, reduced downtime, as well as improved resource allocation [52].
- Accessibility: Efforts are being made to reduce the cost and complexity of adopting automation and robotics. As a result, the technology will be more accessible to a broader range of industries, including SMEs [53].
- Sustainability: The concept of sustainability will be a key focus in the future. Robots and automated systems can play a crucial role in reducing waste and energy consumption [54]. Sustainable practices will become an integral part of automation and robotics design [55].

In conclusion, automation and robotics have significantly impacted industrial processes by enhancing efficiency, precision, and flexibility. The integration of these technologies into manufacturing, healthcare, logistics, agriculture, and other sectors has brought about numerous benefits. However, challenges such as high initial costs, complexity, workforce disruption, safety concerns, and lack of standardization still prevent a more widespread use of these technologies. Nonetheless, the future of automation and robotics is promising, with major research and improvement areas being identified. It is the aim of this Special Issue to document the main developments in this field and bring new prospects for further development in automation and robotics.

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