Research on the Involvement of Intelligent Robots in the Assembly of Modern High-Performance Computers

Researcher II / Lecturer **Iulian Sorin MUNTEANU**[1]**,** PhD student **Viorel NIȚICALĂ**[1]**,**
PhD student **Aurelian ȘTEFĂNESCU**[1]**,** PhD student **Andreea Dana ALIONTE**[1]**,**
Prof. **Ana Maria MUNTEANU**[2]

[1] National University of Science and Technology POLITEHNICA Bucharest

[2] Nikola Tesla Technological High School

* iulian.munteanu0306@upb.ro

Abstract: *This research examines the use of programmed intelligent robots for the assembly process of supercomputers (high-performance computers - HPCs), drawing on multiple and credible/reputable scientific sources, highlighting the impact on the efficiency and quality of this industrial production, flawlessly achieved by handling and assembling the complex components of supercomputers (HPCs), once with reducing errors and improving the accuracy of this complex manufacturing process. The clear advantages of using programmed robots for supercomputer assembly are highlighted in this paper, such as: optimizing production time and reducing labor costs, significant potential to improve production efficiency and quality.*

Keywords: *High-performance computers, intelligent robots, assembly of HPC, artificial intelligence*

1. Introduction

A supercomputer – or a high-performance computer HPC – as it is known in the specialized literature – is an extremely powerful and complex type of computer designed to perform extremely intensive and complex calculations at an incredibly high speed.
These computers are used to solve highly complex scientific and technical problems that require enormous processing power, such as molecular modeling, genome data analysis, climate simulations, and starburst simulations, among others.
A supercomputer/ HPC is composed of a network or cluster of interconnected powerful processors, fast memory and advanced technologies for storing processed data. HPCs can be used in various fields such as: scientific research, design and engineering, financial analysis and even military analysis.
The main characteristics of HPC include massive computing power, a scalable architecture, and the ability to run diverse and complex applications in parallel.
Due to the increased importance of supercomputers/ HPCs in the contemporary world, the need has been created to assemble them as quickly, accurately and reliably as possible, thus giving rise to the idea of using intelligent robots with AI in the industrial environment for the high-quality manufacturing of those.

2. Robots intelligently programmed to assemble high-performance computers

In the last decades, a very large number of robots have been integrated on the production lines of factories, for the purposes of increasing the pace of manufacturing or data with the substantial increase in the quality of the products made. Currently, technological developments allow robots [2-14,17,18] to work interactively with humans in the same environment and within the same process, even without resorting to increased security measures. Communication and easy cooperation between humans and robots (cobots) is the most important requirement in modern working relationships, which has already been successfully achieved in many automated workplaces and even on many technological lines of automated manufacturing, in many countries with highly automated industries.
Moreover, with the development of complex and massive data processing methods, as well as the explosive growth of artificial intelligence in recent years, it has become natural and efficient to

achieve continuous and progressive improvement of intelligent robots by implementing their AI facilities, which thus transformed into extremely capable super-robots for more and more complex, more efficient and more and more autonomous work tasks (see figure 1).

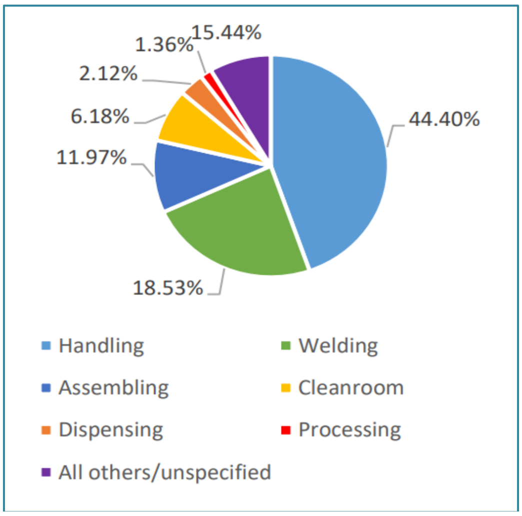

Fig. 1. Share of international distribution of industrial robots by specialized industrial tasks/ operations, in 2022

Artificial intelligence (AI) has successfully entered the field of science and engineering, where a particularly significant development has taken place for the coordination and control of robotic systems and/or intelligent robots [1 -5, 15-18], which have thus acquired superior characteristics, associated with human-level intelligence superior. Artificial intelligence uses several technologies that currently allow robots to understand, feel, plan, act and learn with a level of intelligence equivalent to and often superior to that of humans, so the time perspective creates the premises for highly sophisticated AI robots and with an intelligence far beyond that of the smartest human genius - it is even expected that the future model of AI will surpass all the top human intelligences put together at a given time or that would work closely together like a superman.
Fundamentally, AI systems perceive their surroundings, recognize objects, contribute to complex decision-making, solve, learn from past experiences and imitate patterns, which immediately recommended them as suitable and necessary for intelligent robots (figure 2), with several operational specializations.

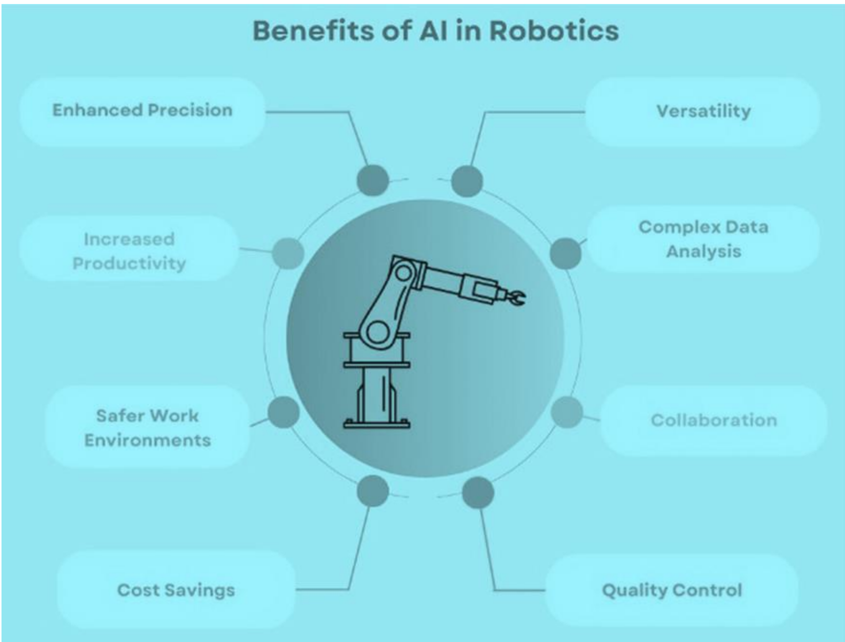

Fig. 2. Benefits of AI implemented on industrial robots in present

On a global level, recent years have highlighted the major role of AI-enabled industrial robots in performing various complex operations and specific tasks across different competitive industries that have significant social impact, such as electronics, manufacturing, automotive, pharmaceuticals, and others.

The main features of modern industrial robots equipped with AI include:

◘ **Programmability**: Industrial robots can be programmed to execute certain operations and very complex movements. Their programming can be tailored to accomplish specific tasks, such as lifting, handling, assembling, welding, painting, inspecting, etc., as well as composite or multiple tasks.

◘ **Repeatability and precision**: They are capable of executing the same operations repeatedly and with high accuracy, which ensures uniformity and maximum quality in production processes.

◘ **Flexibility**: Many models of industrial robots are flexible and can be reprogrammed to perform various tasks or adapt to production changes.

◘ **Robust structure and safety**: Industrial robots are built to withstand harsh working environments and to perform tasks that may be dangerous or difficult for humans. They are also equipped with safety features to prevent accidents around them.

◘ **Use of processing equipment**: They are often outfitted with specialized tools or processing devices, such as welding arms, cutting tools, painting systems, etc., to carry out advanced technological processes on production lines.

◘ **Integration in production lines alongside ai facilities**: These robots are designed to operate efficiently within an industrial production line, collaborating with other autonomous machines and specialized equipment.

The demand for supercomputers, which, in addition to telecommunications and advanced automotive applications, also support autonomous driving, is exponentially increasing in modern society. Consequently, there is a growing need for automation solutions to assemble their component parts.

A compelling example is the automation process at Schnaithmann Maschinenbau GmbH, which has programmed seven KUKA robots to be involved in the production of supercomputers for the German automotive industry.

High-performance supercomputers represent significant brainpower for highly digitized vehicles and, as a result, must process vast amounts of data while being lightweight and compact enough to fit into relatively smaller vehicles. To produce these high-performance supercomputers cost-effectively, efficient and flexible automation solutions were necessary.

In this context, the German automotive industry has turned to KR AGILUS robotic arms, which handle specific urgent components needed for the creation of High-Performance Computers (HPC). Thus, a KR AGILUS robotic arm places the necessary component into the correct compartment of the sequential storage buffers, where another KR AGILUS robot picks up the deposited parts. The process continues with subsequent robotic arms, each programmed individually for another specific operation with each part/component obtained from its predecessor.

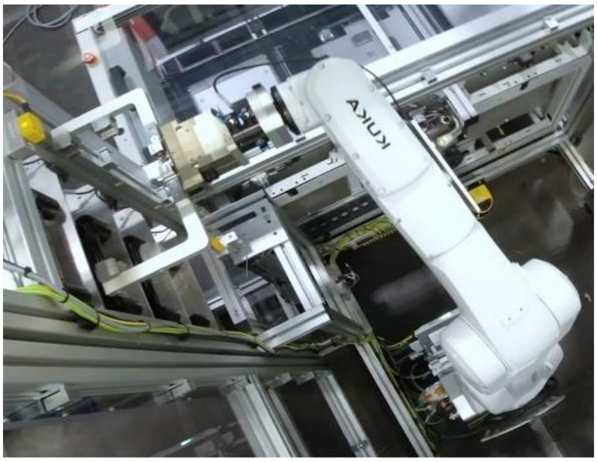

Fig. 3. KR AGILUS robotic arm in automated workflow – View

A successful assembly application involving seven KR AGILUS robots has been developed, which work rapidly and precisely "hand in hand" according to an intelligently programmed technological process in the assembly of modern supercomputers. These KR AGILUS robots (figure 3) never stagnate, do not let anything fall, and assemble and monitor HPC supercomputers with the utmost care; they also contribute to the assembly of vehicles' supercomputers only with the highest quality components by utilizing quality detection facilities for mini-micro-components.
Currently, numerous significant mega-projects have already been completed for international clients using KUKA robots, as these KUKA robots are globally present in many highly technological countries and in various high-tech applications related to Industry 4.0.
The optimized and slender construction of the KR AGILUS arm, along with its versatile real-world utilization capabilities combined with the compact control module of the KR C5 robot, were among the main reasons that propelled this type of KUKA industrial robots into the launch of a massive innovative automation initiative for supercomputer manufacturing, which began globally with the end of 2021, led by the global leader in industrial automation, KUKA.

2.1 KUKA Robots in Chaku-Chaku Workflow

Industrial robotic automation at an international level often employs assembly lines with conveyor belts; however, this approach imposes strict limitations on manufacturing enterprises, as products are initially designed within a specific range of dimensions. If there are dimensional changes to the product, even partially, at the end of the production line, costly structural modifications will be necessary due to the existing intrinsic limitations of the conveyor systems.
As a countermeasure, a technical solution featuring multiple autonomous robots working in tandem, without conveyor belts, has been proposed—this is known as the Chaku-Chaku principle.
The Chaku-Chaku principle eliminates the need for additional transport means, such as traditional conveyor belts, between various workstations. In this setup, robots transfer parts directly from one station to another, sequentially performing specific processing actions at each workstation. This approach provides greater flexibility for future adjustments to the workstations, as robots can be easily relocated and reprogrammed to different manufacturing areas.
However, the Chaku-Chaku principle requires that the robots communicate intelligently with one another and effectively manage their working spaces. The classic Chaku-Chaku handling application allows robots in an open space to execute their operational steps in a predefined order.
Furthermore, for Chaku-Chaku applications, the six-axis robot is ideally suited to be paired with the KR C5 micro control module, which is notably compact and energy-efficient.
The compact design of the KR AGILUS, combined with one of the most compact robot control modules available on the international market, ensures maximum flexibility and cost-effectiveness for the assembly of HPC supercomputers.
Moreover, KUKA has recently demonstrated through an ambitious research project that the mobile robot KMR iiwa is highly suitable for rapidly equipping printed circuit boards (PCBs) with components. This is made possible thanks to its unique features that combine the advantages of the lightweight sensitive robot LBR iiwa with a mobile and autonomous platform, rendering it location-independent and highly flexible. As part of the splicing process, the KMR iiwa reliably, quickly, and accurately places sensitive component parts into designated positions on the PCB.

2.2. Use of KUKA Robots for Supercomputer Assembly Processes through Voice Control

The software developed by KUKA for the assembly processes of supercomputers using voice control includes several subprograms for sequential processing. The subprograms, flowchart, and data types are illustrated in figure 4.
The logical flow of using human vocal language to coordinate the KUKA industrial robot is depicted as a logical diagram and can be understood through the explanations provided below:
- At the beginning of the recording, a single sound "Beep!" is heard, followed by a double sound "Beep! Beep!" through the headset when the recording has concluded.
- The recording starts as automated and continues in an infinite loop.
- The operator records voice data by speaking naturally into the microphone.

If the spoken data or commands do not conform to the "typical KUKA voice data format," the recording resumes between the "Beep!" sounds.

If the voice data are "typical KUKA voice data," the duration between a single "Beep!" and a double "Beep! Beep!" is adjusted to allow for the recording of additional voice data.

• The recorded voice data are converted into text through Automatic Speech Recognition (ASR) and subsequently transmitted to the Improvement Module of Mispronounced Words (IMMW) to obtain enhanced data for the intelligent robot.

• At this stage, the operator must confirm the task assigned to the robot by pronouncing commands such as "Evet" (yes) or "Hayır" (no).

If the recorded voice data do not match the operator's speech, the operation returns to the initial step of issuing voice commands.

If the assigned task corresponds to the task requested by the operator, the Text Understanding (TU) unit is activated. The robot then transitions to the object detection module within its workspace, activating the robot's position control. This immediately leads to the activation of the specific movements required for the operations requested by the human operator, who continually analyzes, through visual sensors and a nearby display, how the robot's movements align with the verbally assigned tasks from a distance relative to the operational area of the intelligent robot.

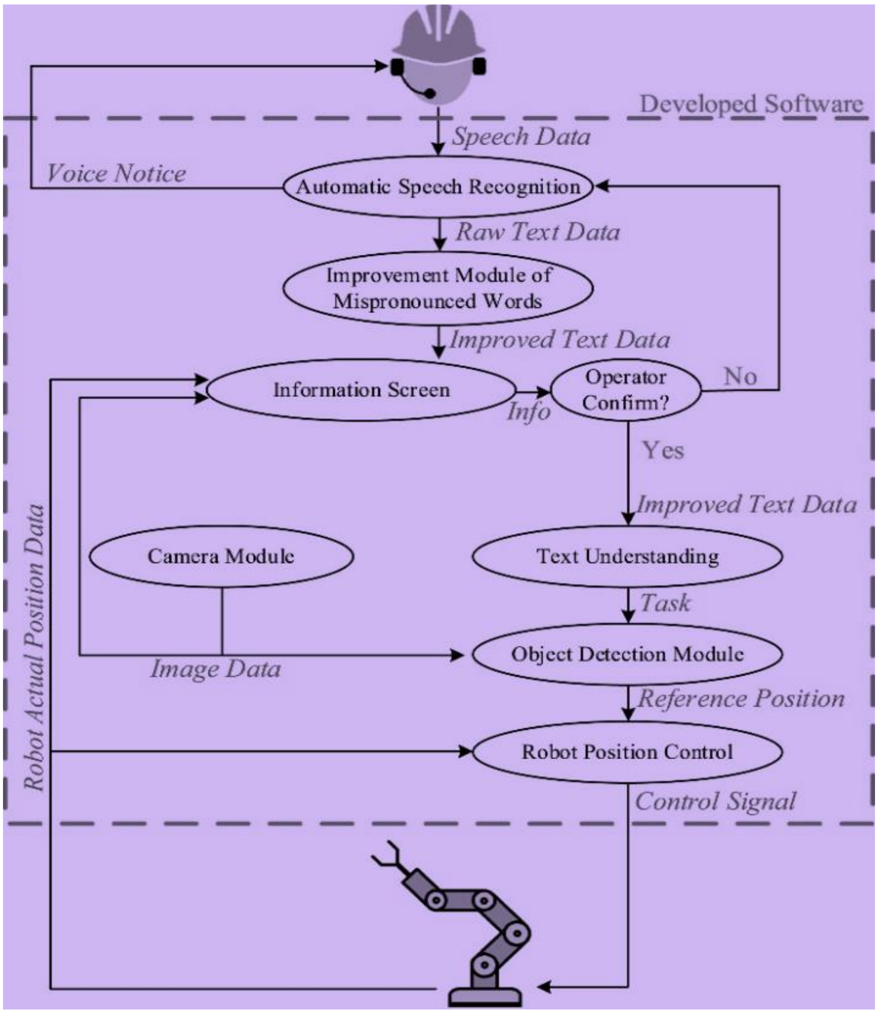

Fig. 4. Software developed by KUKA for voice-controlled supercomputer assembly processes. Logical scheme

2.3. Software developed for understanding surroundings by intelligent robots and mapping a specific sequential trajectory

This dedicated software consists of convolutional neural network (CNN) modules designed for the following roles: process selection, trajectory generation, and regulation of the sequential trajectory to be executed. The KUKA software developed and the data traffic between the CNN modules are presented in figure 5.

A video camera was used to make the robot aware of its environment and to perceive the desired process. The camera's task was to record the movement of the operator's hand within the robot's workspace. The operator starts the video recording before the operation, and the recording is stopped by the operator when the demonstration of the defined process is completed.
Once the video recording is separated into images, these images are sent to the CNN structure. The CNN classifies the images based on hand gestures. In the selection process and trajectory generation module, the type of operation and the start and end timings are selected, such as welding or sealing, which are determined by the hand movements.
The trajectory of the process is then calculated, and the obtained trajectory is subject to the operator's approval. If the operator does not confirm the process or the obtained trajectory, the system returns to the video recording stage. If the operator confirms the action and the trajectory, the trajectory regulation phase follows, which is again confirmed by the operator. Subsequently, the determined process is executed by the KUKA KR AGILUS robot. After the process of a specific trajectory is completed, the program returns to the initial stage.

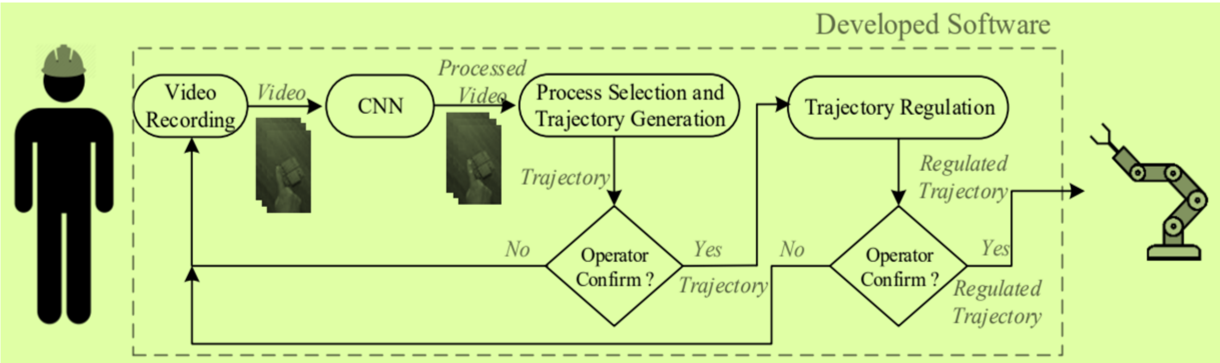

Fig. 5. Developed KUKA software and data traffic between CNN modules

3. Conclusions

It can be concluded that the success of high-performance computers (HPC) constructions [5-9, 17,18] with the help of intelligently programmed robots is fundamentally based on the direct and consistent contribution of AI. As mentioned earlier, artificial intelligence is continuously experiencing qualitative growth and expansion into various fields of science and diverse human activities, which astonishes us every day, but also generates concerns due to the unclear regulations currently governing the functioning of AI in public spaces, which often have an overly broad and uncontrolled access for a diverse public that can sometimes be unethical in behavior.
Even large global companies have turned their attention to the development of artificial intelligence, striving to create the most powerful AIs possible. A recent example from the media is Mark Zuckerberg's promise to develop this type of artificial intelligence at an ultra-advanced level, practically the most powerful AI that could match human intelligence, and be open to the public. "This technology is so important and the opportunities are so great that we should open it up and make it available at the largest possible scale in a responsible manner, so everyone can benefit", stated entrepreneur Mark Zuckerberg.
On the other hand, experts estimate that the need for supercomputers HPC for innovative electric vehicles will continue to grow, and automation solutions such as those offered by KUKA contribute to meeting the high demand for high-performance computing (HPC) and the cost-effective and reliable long-term production of these HPCs.
Currently, several automotive suppliers are known to be working with KUKA and their integrators on other innovative solutions for the future of mobility through the implementation of high-performance computers (HPC).

References

[1] Ye, R., and Q. Dai. "Implementing transfer learning across different datasets for time series forecasting." *Pattern Recognition* 109 (January 2021): 107617. doi: 10.1016/j.patcog.2020.107617.

[2] Bingol, M. C., and O. Aydogmus. “Practical application of a safe human-robot interaction software.” *Industrial Robot* 47, no. 3 (2020): 359–368. doi: 10.1108/IR-09-2019-0180.
[3] Bingol, M. C., and O. Aydogmus. “Performing predefined tasks using the human–robot interaction on speech recognition for an industrial robot.” *Engineering Applications of Artificial Intelligence* 95 (October 2020): 103903. doi: 10.1016/j.engappai.2020.103903.
[4] Li, C., S. Zhang, Y. Qin, and E. Estupinan. “A systematic review of deep transfer learning for machinery fault diagnosis.” *Neurocomputing* 407 (September 2020): 121–135. doi: 10.1016/j.neucom.2020.04.045.
[5] Ghiasvand, Siavash, and Florina M. Ciorba. “Anomaly Detection in High Performance Computers: A Vicinity Perspective.” Paper presented at the 18th International Symposium on Parallel and Distributed Computing (ISPDC 2019), Amsterdam, the Netherlands, June 5-7, 2019.
[6] Hager, Martin, Przemyslaw Gromala, Bernhard Wunderle, and Sven Rzepka. “Affordable and Safe High Performance Vehicle Computers with Ultra-Fast On-Board Ethernet for Automated Driving.” Paper presented at the 22nd International Forum on Advanced Microsystems for Automotive Applications (AMAA 2018) "Smart Systems for Clean, Safe and Shared Road Vehicles", Berlin, Germany, September 11-12, 2018.
[7] Ginsberg, Myron. “Creating an Automotive Industry Benchmark Suite for Assessing the Effectiveness of High-Performance Computers.” *SAE Transactions* 104, Section 6: Journal of Passenger Cars, Part 2 (1995): 2048-2057.
[8] Schneiders, Lennart, Jerry H. Grimmen, Matthias Meinke, and Wolfgang Schröder. “An efficient numerical method for fully resolved particle simulations on high performance computers.” *PAMM - Proceedings in Applied Mathematics and Mechanics* 15, no. 1 (October 2015): 495-496.
[9] Kang, Jia, Naiyuan Chiang, Carl D. Laird, and Victor M. Zavala. “Nonlinear programming strategies on high-performance computers.” Paper presented at the 54th IEEE Conference on Decision and Control (CDC), Osaka, Japan, December 15-18, 2015.
[10] Peternel, L., N. Tsagarakis, and A. Ajoudani. “A human-robot co-manipulation approach based on human sensorimotor information.” *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 25, no. 7 (July 2017): 811-822. doi: 10.1109/TNSRE.2017.2694553.
[11] Ding, H., M. Schipper, and B. Matthias. “Collaborative behavior design of industrial robots for multiple human-robot collaboration.” Paper presented at the 44th International Symposium on Robotics, IEEE ISR 2013, Seoul, South Korea, October 24-26, 2013.
[12] Rahman, S. M. M., Y. Wang, I. D. Walker, L. Mears, R. Pak, and S. Remy. “Trust-based compliant robot-human handovers of payloads in collaborative assembly in flexible manufacturing.” Paper presented at the 2016 IEEE International Conference on Automation Science and Engineering (CASE), Fort Worth, Texas, USA, August 21-25, 2016.
[13] Hamabe, T., H. Goto, and J. Miura. “A programming by demonstration system for human-robot collaborative assembly tasks.” Paper presented at the 2015 IEEE International Conference on Robotics and Biomimetics (ROBIO), Zhuhai, China, December 6-9, 2015.
[14] Ding, H., J. Heyn, B. Matthias, and H. Staab. “Structured collaborative behavior of industrial robots in mixed human-robot environments.” Paper presented at the 2013 IEEE International Conference on Automation Science and Engineering (CASE), Madison, Wisconsin, USA, August 17-20, 2013.
[15] Franchi, Matt W. *Webots.HPC: A Parallel Robotics Simulation Pipeline for Autonomous Vehicles on High Performance Computing*. Bachelor Thesis. Clemson University, August 2021.
[16] Cyberbotics Ltd. “Webots documentation: Webots User Guide”. Accessed September 1, 2024. https://cyberbotics.com/doc/guide/index.
[17] KUKA AG. “KMR iiwa”. Accessed September 2, 2024. https://www.kuka.com/ro-ro/produse-servicii/amr-robotica-mobila-autonoma/mobile-robot-systems/kmr-iiwa.
[18] KUKA AG. “Construction of facilities for the automotive sector” / “Construcția de instalații pentru sectorul automobilelor”. Accessed September 3, 2024. https://www.kuka.com/ro-ro/produse-servicii/instala%c8%9bii-de-produc%c8%9bie/construc%c8%9bia-de-instala%c8%9bii-pentru-industria-auto.