

SESSION C:

PRODUCTION TECHNOLOGIES, CAE AND MANAGEMENT

Robot-assisted lathe machine servicing

Vojislav Vujičić^{1*}, Ivan Milićević¹, Nenad Mijailović¹, Nedeljko Dučić¹, Veljko Aleksić¹, Marko Popović¹

¹ University of Kragujevac, Faculty of Technical Sciences Čačak, Čačak, Serbia

ARTICLE INFO

* Correspondence: vojislav.vujicic@ftn.kg.ac.rs

DOI: <https://doi.org/10.46793/ET26.C02V>

PAGES: C13 – C18

ABSTRACT

This paper describes a simulation of an industrial robot-assisted lathe servicing process using ABB RobotStudio software. The objective of the simulation is to demonstrate how integrating a robot for material handling can improve productivity and ensure safer operation within a manufacturing environment. The first part of the paper outlines the procedure for importing 3D models of robots and the lathe into the simulation environment. Special focus is placed on defining the lathe's movable elements, such as its door, as well as a conveyor belt for moving finished parts outside the safety zone. Key operational parameters were established, including target positions for the robot (pick-up from the raw material storage, insertion into the chuck, and deposition onto the conveyor) and the robot's movement trajectory. Based on these, an optimized RAPID program was developed to control the robot and other moving components during the simulation. The final stage includes testing and visual evaluation of the entire process, confirming both the system's functionality and the robustness of the proposed automation solution.

KEYWORDS

Industrial robot, CNC lathe machine, Workpiece handling, Simulation.

1. INTRODUCTION

The rapid development of industrial automation technologies has transformed manufacturing processes across numerous industrial sectors. [1] Modern production facilities increasingly rely on automated systems to achieve higher productivity, lower operational costs, and improved product consistency. [1] Among the technologies driving this transformation, industrial robotics plays a central role due to its flexibility, precision, and capability to perform repetitive tasks continuously with minimal human intervention. [1] [2].

Industrial robots are currently employed in a wide variety of applications, including assembly, welding, packaging, palletizing, quality inspection, and machine tending. [3] Machine tending applications are particularly important because they directly influence production throughput and machine utilization. [4] In conventional manufacturing environments, machine loading and unloading operations are frequently performed manually, exposing operators to repetitive tasks, physical strain, and potential safety hazards. [4] The integration of robotic systems can eliminate these disadvantages while simultaneously improving process reliability and consistency. [3]

The implementation of industrial robots within machining environments has become increasingly common due to advancements in robot control systems, sensor technologies, and simulation software. [5] Modern offline programming platforms enable engineers to design, optimize, and validate robotic systems before physical deployment, and the use of offline programming reduces costs and risks, enables rapid tuning of robot paths, and minimizes collision states. [6] This approach reduces commissioning time, minimizes implementation risks, and lowers overall project costs. [6] By utilizing digital models of industrial equipment, engineers can identify potential problems and optimize system performance before installation in a real production environment. [6]

2. SIMULATION ENVIRONMENT AND SYSTEM COMPONENTS

The simulation was developed using ABB RobotStudio, a comprehensive software platform designed for robotic system modeling, offline programming, and virtual commissioning. The software provides tools for creating realistic workcell environments and testing robotic applications under conditions closely resembling real industrial operation.

The primary robotic component selected for this application was the ABB IRB120 industrial manipulator. This six-axis robot is characterized by compact dimensions, high repeatability, and excellent suitability for precision handling tasks. Due to its relatively small footprint and flexible motion capabilities, the robot represents an appropriate choice for machine-tending applications in compact manufacturing cells.

The robotic workcell consists of several interconnected components that collectively enable automated operation:

- ABB IRB120 industrial robot;
- Haas ST-10 CNC lathe machine;
- Two-finger robotic gripper;
- Conveyor belt system;
- Raw material storage location;
- Finished-part storage container;
- Safety enclosure and operator access zone.

To ensure realistic simulation conditions, a detailed three-dimensional model of the Haas ST-10 lathe machine was imported into RobotStudio (figure 1). Since the original machine model was available in CAD formats unsuitable for direct use within the simulation environment, it was converted into a compatible format before importation.

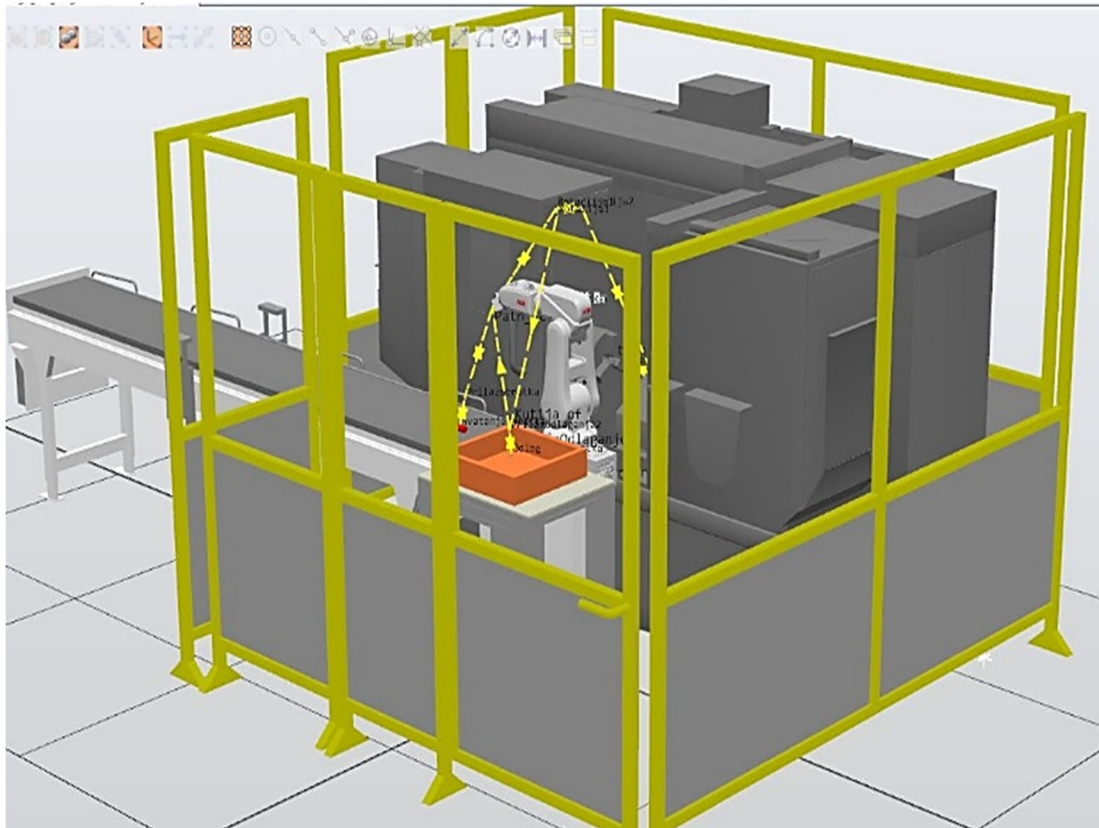


Figure 1: Robotic workcell

Modeling the lathe machine's sliding door mechanism received special attention. The opening and closing of the machine door represent a critical operation because it directly affects the interaction between the robot and the machine tool. Therefore, the door was implemented as a separate mechanical component with predefined motion constraints and operating states. A conveyor system was incorporated into the simulation to facilitate automated transportation of finished workpieces outside the robot operating area. This addition improves process continuity and reflects common industrial practices in automated machining cells. Finally, safety fencing and access gates were included to replicate realistic factory conditions and ensure compliance with industrial safety requirements. These elements also contribute to the overall realism of the virtual manufacturing environment.

3. MODELING OF THE ROBOTIC WORKCELL

After importing the required components, the next stage involved configuring and positioning the equipment within the virtual workspace. The layout design process aimed to maximize robot accessibility while minimizing unnecessary movement and ensuring collision-free operation. The lathe machine was positioned within the robot working envelope to allow efficient loading and unloading operations. The machine door mechanism was modeled as a prismatic joint with predefined open and closed positions (figure 2). Transition times between positions were configured to accurately replicate realistic machine behavior during production cycles.

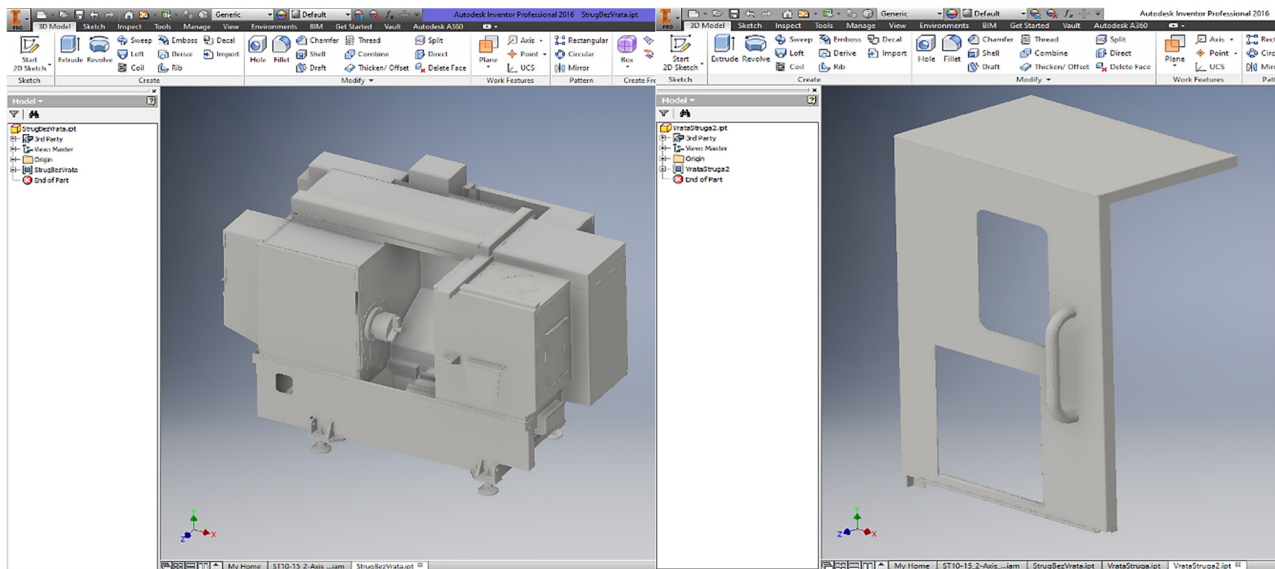


Figure 2: 3D model of lathe machine and door mechanism

The robotic gripper was modeled according to manufacturer specifications. A two-finger design was selected because of its simplicity, reliability, and suitability for handling cylindrical workpieces. The gripper mechanism was implemented with rotational joints representing the motion of the fingers during opening and closing operations shown on figure 3.

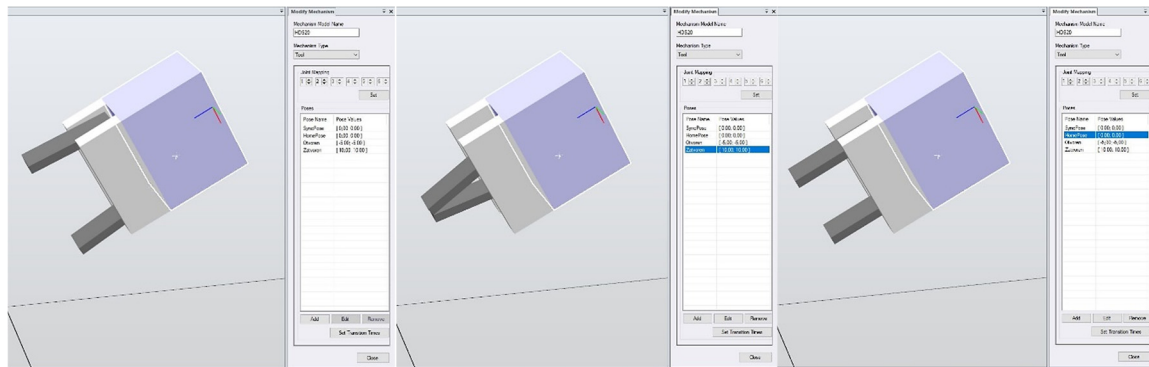


Figure 3: Robotic pneumatic gripper with rotation joints

Special attention was devoted to defining the Tool Center Point (TCP), which represents the reference point used by the robot controller during motion planning. Accurate TCP positioning is essential for ensuring precise manipulation of workpieces and repeatable robot operation. The simulation also required defining the physical properties of the gripper, including mass and center of gravity. These parameters influence robot dynamics and improve the realism of simulated motion.

Several work objects and coordinate systems were established throughout the workcell. Dedicated coordinate frames were assigned to the conveyor system, raw material location, machine chuck, and finished-part container (figure 4). The use of local coordinate systems simplifies robot programming and improves system flexibility, allowing modifications to individual components without extensive reprogramming.

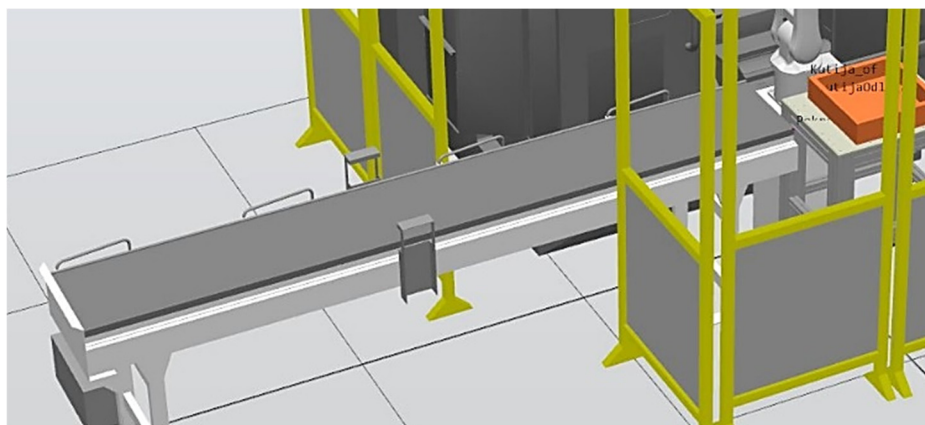


Figure 4: Conveyor belt with raw material location and finished part container

Safety considerations were incorporated during the layout design process. Robot reachability analysis and workspace visualization tools available in RobotStudio were used to verify that all required task locations were accessible without violating mechanical limitations or causing collisions.

4. ROBOT PROGRAMMING AND PROCESS SEQUENCE

Once the workcell configuration was completed, robot trajectories and control logic were developed using ABB RAPID programming language. The objective was to create a reliable and efficient operational sequence capable of servicing the lathe machine autonomously.

The first step involved defining a series of robot targets corresponding to important process locations. These targets represent specific positions and orientations that the robot must reach during operation. The main targets included:

- Home position;
- Material pickup position;
- Approach position above the raw material;
- Lathe loading position;
- Lathe unloading position;
- Finished-part placement position.

The robot motion strategy combined two different movement types. Joint-interpolated motions (MoveJ) were employed for rapid travel between distant locations because they minimize cycle time. Linear-interpolated motions (MoveL) were used whenever precise tool movement was required, particularly during insertion and extraction of workpieces from the machine chuck (figure 5).

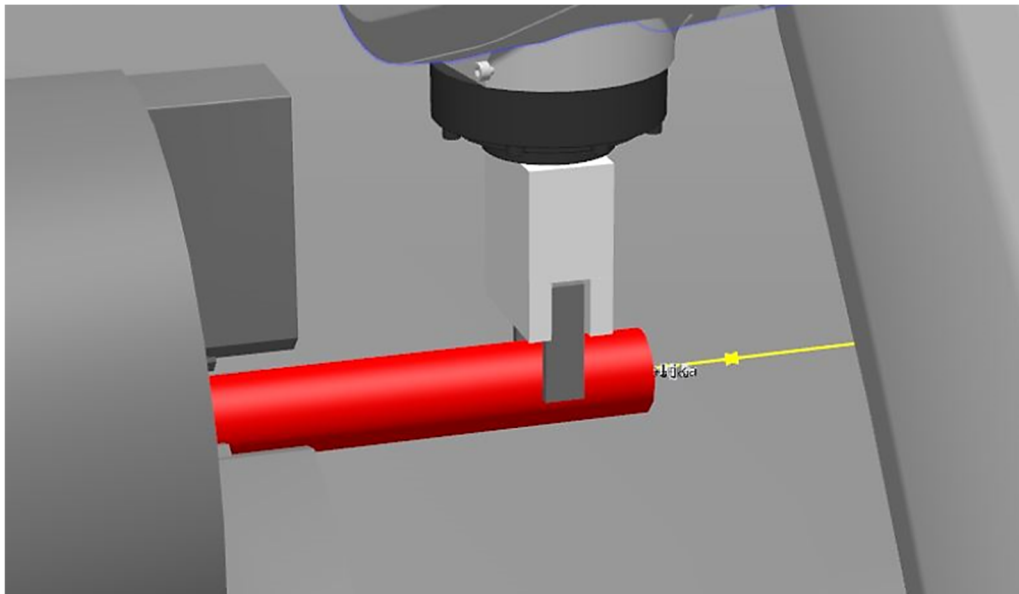


Figure 5: Insertion/extraction of workpieces from the machine

To coordinate the robot with external devices, several digital input and output signals were implemented. These signals enabled communication between the robot controller, machine tool, gripper, and conveyor system. The primary control signals were responsible for:

- Opening and closing the gripper;
- Opening and closing the machine door;
- Attaching and releasing workpieces;
- Resetting workpiece positions;
- Synchronizing robot and machine operations.

The complete production cycle begins with the robot positioned at its home location. The robot then moves toward the raw material storage area and approaches the workpiece using a controlled linear trajectory. Once the workpiece is grasped, the robot transports it toward the CNC lathe. Robot positions are shown in figure 6.

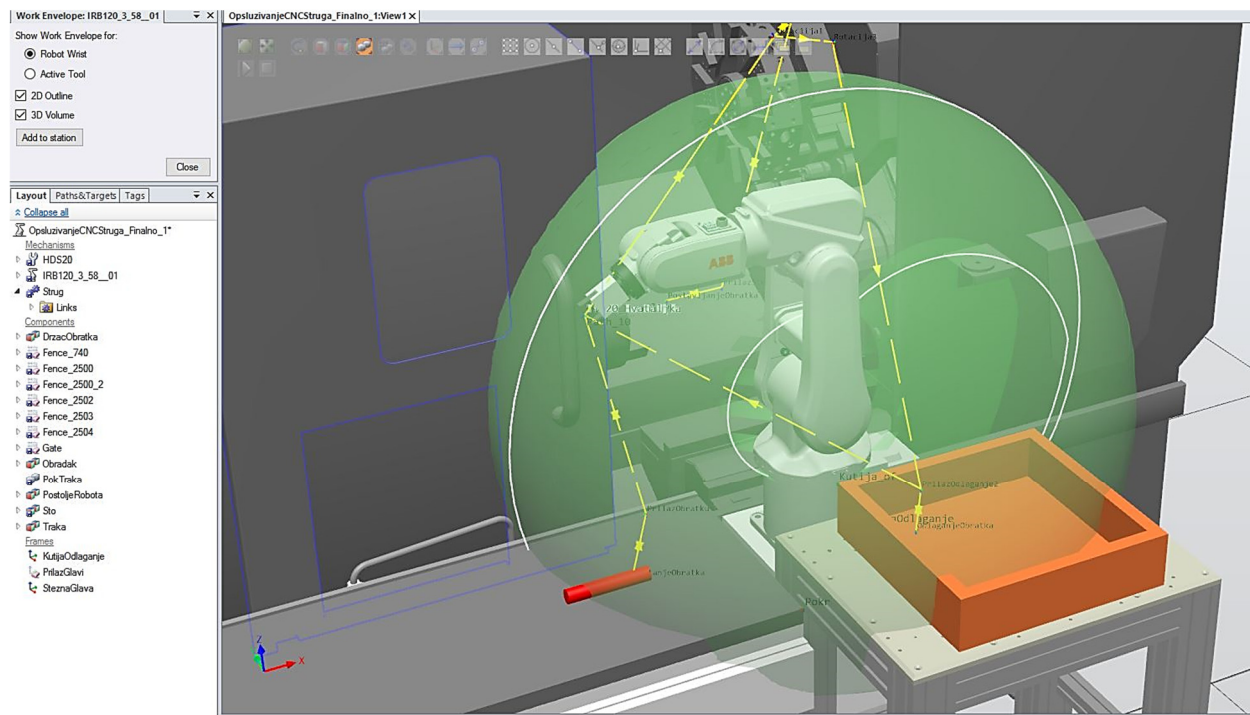


Figure 6: Robot with characteristic points and trajectories

Before loading the workpiece, the robot activates the door-opening sequence. After confirmation that the door has reached its open position, the robot inserts the workpiece into the chuck using carefully controlled linear motion. The gripper releases the part, and the robot retreats to a safe waiting position.

Following the machining operation, the door opens again, allowing the robot to remove the finished part. The workpiece is then transferred either to a conveyor system or to a designated storage container. After completing the unloading process, the robot returns to its home position and waits for the next production cycle.

5. SIMULATION RESULTS AND DISCUSSION

The developed robotic workcell was extensively tested within the RobotStudio simulation environment. Multiple simulation runs were conducted to evaluate the reliability of robot motion, verify synchronization between components, and identify potential operational issues.

The results confirmed that all programmed robot trajectories were successfully executed without collisions. The robot maintained safe distances from surrounding equipment while efficiently accessing each required process location.

The simulation demonstrated successful interaction between the robot and the machine tool throughout the complete servicing cycle. The implemented synchronization logic ensured that loading and unloading operations were performed only when the machine door was fully open and the machining process had been completed.

Workspace analysis showed that the selected robot configuration provides adequate reachability for all required tasks. Furthermore, trajectory optimization reduced unnecessary robot motion and contributed to improved cycle efficiency.

The virtual commissioning approach provided several important benefits. Potential design issues were identified and corrected before physical implementation, significantly reducing development costs and commissioning time. Additionally, the simulation environment enabled detailed evaluation of process performance without disrupting production or requiring expensive hardware modifications.

The results clearly demonstrate that robotic machine tending can provide substantial improvements in productivity, consistency, and operational safety compared with manual operation. The developed simulation therefore represents a valuable step toward practical deployment of the proposed automation solution.

6. CONCLUSION AND FUTURE WORK

This paper presented the design, programming, and simulation of a robotic machine-tending system for servicing a CNC lathe using an ABB IRB120 industrial robot. A complete virtual workcell was developed within ABB RobotStudio, including realistic models of the machine tool, robotic manipulator, gripper, conveyor system, and safety infrastructure.

The simulation successfully demonstrated the feasibility of fully automating the loading and unloading operations associated with CNC machining processes. Through careful trajectory planning, implementation of RAPID control logic, and synchronization of robot actions with machine operations, the system achieved reliable and collision-free performance.

The obtained results indicate that robotic integration can significantly improve manufacturing efficiency, reduce operator involvement in repetitive tasks, enhance workplace safety, and increase overall process consistency. Moreover, the use of simulation technology enables engineers to evaluate and optimize automation solutions before deployment, reducing both implementation risks and development costs.

Future research will focus on incorporating machine vision systems for automatic part localization, integrating advanced sensor technologies for adaptive process control, improving synchronization strategies between the robot and machining equipment, and developing a physical prototype of the workcell. Additional optimization techniques, including cycle-time reduction and intelligent scheduling algorithms, may further enhance the performance of the proposed manufacturing system.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for its financial support in the realization of this research, based on Contract No. 451-03-34/2026-03/200132 concluded between the Faculty of Technical Sciences in Čačak and the aforementioned Ministry.

REFERENCES

- [1] R. A. Adebayo, N. C. Obiuto, I. C. Festus-Ikhuoria, and O. K. Olajiga, "Robotics in Manufacturing: A Review of Advances in Automation and Workforce Implications," *International Journal of Advanced Multidisciplinary Research and Studies*, <https://doi.org/10.62225/2583049X.2024.4.2.2549>, (2024).
- [2] J. Howard et al., "Industrial Robotics and the Future of Work," *American Journal of Industrial Medicine*, <https://doi.org/10.1002/ajim.23729>, (2025).
- [3] M. Soori, F. K. G. Jough, R. Dastres, and B. Arezoo, "Robotical Automation in CNC Machine Tools: A Review," *Acta Mechanica et Automatica*, <https://doi.org/10.2478/ama-2024-0048>, (2024).
- [4] Prof. C. C. Jadhav, Mr. A. Mr. R. Kale, K. Mr. M. G. Khandalkar, M. S. Ingale, and R. Bhandare, "Design and Manufacturing of Robotic Arm for Industrial Applications," *International Journal of Engineering Technology and Management Sciences*, <https://doi.org/10.46647/ijetms.2023.v07i04.032>, (2023).
- [5] R. G. Chittawadigi and D. E. Rendi, "Systematic Overview of Development of a Robot Kinematics Library for Motion Planning of Serial Robots Using Object Oriented Programming Concepts," *IEEE International Conference on Robotics and Biomimetics*, <https://doi.org/10.1109/robio64047.2024.10907363>, (2024).
- [6] M. Komák, E. Pivarčiová, and P. Herčút, "Machining of Printed Circuit Boards Using an Industrial Robot in a Simulation Environment," *Management Systems in Production Engineering*, <https://doi.org/10.2478/mspe-2025-0042>, (2025).