# Simulation Study of Industrial Robots Based on Offline Programming

Junyu Liu
*North Broward Preparatory School, Coconut Creek, Florida, 33073, U.S.A.*

Keywords: Automatic Driving, Offline Programming, Matlab and Simulink, Route Planning, Anti-Obstacle Technology.

Abstract: With the wide application of industrial robots in the production field, the manufacturing industry requires higher productivity and quality, and path planning and simulation technology becomes a critical factor in improving machine learning. This study focuses on industrial robot path planning and simulation and the application of Matlab and Simulink in its technology, aiming to improve productivity, reduce cost, and promote sustainable development. In order to further improve the accuracy of path planning and the efficiency of robot motion control, machine learning techniques and numerical stability are optimized. For industrial robot path planning and simulation, Matlab and Simulink simulation techniques are used to study the kinematic characteristics of the robot and path planning algorithms in depth. By optimizing the offline programming and path planning algorithms, the efficient operation of the robot in complex environments is achieved, and the error rate in the production process is reduced. In addition, obstacle avoidance technology also provides the robot with critical environment sensing capability when performing tasks, further improving the production line's safety and productivity. Overall, this study provides relevant technical support and theoretical guidance for applying industrial robots, which helps improve production efficiency, reduce costs, and realize sustainable development.



## 1 INTRODUCTION

The digital transformation of the manufacturing industry has led to an increasing importance of industrial robots in production. The rapid development of digital technology has made manufacturing production more automated and intelligent. Industrial robots are a key component of digital production due to their high precision, high performance, and long working hours. They have become an important driving force in improving product quality and production efficiency. Industrial robots possess high precision operation and production line automation capabilities (Liu 2022). They can seamlessly link the accuracy of the manufacturing process by replacing traditional manual labor, thereby reducing labor costs. Additionally, industrial robots excel in handling high temperatures, high pressures, and hazardous scenarios, reducing the risk of injuries from human labor and ensuring the safety of the production process. The significance of industrial robots is evident in their ability to rapidly adapt to changes in production requirements, particularly in offline programming based on industrial robot simulation studies (Hu et al 2023).

As mentioned above, the strength of robots lies in their ability to perform highly repetitive tasks, and offline programming further improves productivity by optimizing the execution paths of these tasks. Within the literature review, several studies have emphasized the importance of offline programming in terms of enhancing robot performance and productivity (Zhao et al 2023). For example, Prof. Peng Li investigated intelligent perception, decision-making and sensing systems for robots to improve their autonomy and adaptability in complex environments. In addition, Oussama Khatib studies robot path planning and motion planning, primarily motion planning algorithms in complex environments to ensure that robots can perform tasks efficiently and safely. Finally, path planning plays a vital role in offline programming. Path planning is to ensure that robots can efficiently perform tasks in real-world applications. In-depth Research and improvement of algorithms can further increase the efficiency of robot motion, reduce energy consumption, and decrease the risk of potential collisions. Although the application



Liu, J.
Simulation Study of Industrial Robots Based on Offline Programming.
DOI: 10.5220/0012837100004547

In *Proceedings of the 1st International Conference on Data Science and Engineering (ICDSE 2024)*, pages 537-541
ISBN: 978-989-758-690-3

of robotics in the manufacturing industry is gradually deepening, it is facing problems such as high cost and long lead time of physical research and development methods. In order to customer service these limitations, offline programming techniques have emerged to provide an innovative way for the Research and development of industrial robots.

This paper aims to thoroughly investigate the application of Matlab and Simulink in path planning and obstacle avoidance techniques to optimize the motion trajectory and improve the performance of industrial robots for more efficient automated production. By overcoming the various limitations of physical Research, it provides some ways and ideas for developing industrial robots, which is of great theoretical and practical significance for improving production efficiency, reducing costs and realizing sustainable development.

## 2 OVERVIEW OF TECHNOLOGY IN AUTOMATED SYSTEMS

In order to improve the working performance of robots and automated production efficiency, path planning and offline programming have become a hot spot of current Research. Offline programming is the creation of a three-dimensional simulation of the robot and computer numerical control (CNC) machine tools through software simulation calculations to generate the control robot trajectory, and then generate the robot's control instructions. This allows engineers to control robots and CNC machines in a physical environment (Fu et al 2022). This technology offers unique advantages to manufacturing companies and is expected to solve the problems of high programming costs and long test cycles. First, offline programming allows the robot to be programmed independently of the actual production line, reducing the number of days or even weeks that engineers must spend in downtime programming the robot's tutorials. Secondly, offline programming helps to improve the accuracy and efficiency of the robot's work. With highly accurate simulations in a virtual environment, robots can perform tasks in simulation, allowing for more accurate workflow planning. It helps reduce the production process's error rate and improve product quality. Path planning can significantly improve the efficiency of the robot (Li et al 2022). By accurately calculating the optimal path in 3D simulation, robots can complete tasks faster and more resource-efficiently, increasing the productivity of the entire production line. In industrial automation, obstacle avoidance technology, as an important complement to path planning, enables robots to sense the surrounding environment and road conditions in real time while performing path planning through intelligent algorithms and sensor systems. This helps robots to operate efficiently in complex environments and avoid collisions and work interruptions.

The application of path planning and obstacle avoidance technology is not only limited to the familiar field of self-driving cars and drones but also more widely penetrates the field of simulation control. Path planning, as a core component of an autonomous driving system, has the task of simulating various road conditions, traffic situations and obstacles in a virtual environment and determining the reliability, safety and efficiency of an autonomous driving system in an actual road environment. Along with path planning, obstacle avoidance technology has evolved and become integral to system development (Zhang 2007 & Xu 2021). The system realizes high-precision sensing of the surrounding environment by integrating multiple sensors, such as LIDAR and cameras. Despite significant progress in these technologies, several challenges remain, including model accuracy and high sensor costs. In the face of these problems, optimizing system architectures and algorithms becomes a key way to reduce cost and improve performance.

## 3 TECHNOLOGY APPLICATIONS IN AUTONOMOUS DRIVING SYSTEMS

In autonomous driving systems, path planning aims to help vehicles find the optimal path in the road network to ensure safe, efficient, and traffic-compliant driving. In real-world driving, this involves comprehensively considering factors such as road conditions, traffic flow, constraints, and target locations. To validate the path planning algorithms for self-driving vehicles, researchers have placed them into a virtual environment for simulation. This virtual approach provides researchers with a safe and controlled test scenario that allows them to evaluate the performance of the system in different complex scenarios. By simulating various possible scenarios, path planning algorithms can be validated and improved in simulation, thus improving the feasibility of the system in real road environments (Zhang 2006).

Another key aspect is the companion technology to path planning, namely obstacle avoidance. Obstacle avoidance technology is crucial in automatic driving systems, and its core lies in realizing high-precision perception of the surrounding environment by integrating multiple sensors (Zhou and Li 2018). Light detection and ranging (LiDAR), as one of the key technologies, provides the system with accurate and reliable environmental data and key information for vehicle navigation safety and obstacle avoidance. The distance information of surrounding objects is obtained by emitting laser beams and measuring their bounce time to construct an accurate 3D map for the system. This method continuously updates the map as the vehicle travels, allowing the system to promptly be aware of static and dynamic obstacles on the road so that it can adjust its path planning strategy. Meanwhile, computer vision algorithms analyze the content of the color images captured by the camera to provide a further understanding of the environment.

However, despite the significant progress these techniques have brought, there are still some challenges. The first is modeling accuracy. Simulation environments must be able to accurately simulate a variety of weather conditions, road types, and driver behaviors in reality. For example, inclement weather, such as rain or snow, may affect the performance of the sensors under different weather conditions, thereby affecting the accuracy of path planning. The next issue is cost. The high cost of sensors limits the wide application of these technologies. To solve this problem, in addition to optimizing the system architecture and algorithms, reducing the cost of sensor manufacturing has become an important research direction. By streamlining system components, improving the efficiency of algorithms, and promoting the innovation of sensor technologies, the manufacturing cost of the overall system can be effectively reduced, thus making these technologies more feasible and sustainable.

# 4 MATLAB IN INDUSTRIAL ROBOT PATH PLANNING AND SIMULATION OF KEY TECHNOLOGY AND APPLICATION

Regarding path planning, introducing machine learning technology provides the system with stronger learning and adaptation capabilities (Li et al 2022). By learning from many driving scenarios, the machine learning algorithms can better adapt to unknown or dynamic environments, which in turn accelerates the path-planning process. This deep learning approach is trained in a virtual environment to continuously improve the system's adaptability to complex situations and enhance its real-time performance on real roads.

Optimization in digital stability involves the accuracy of sensor data and the real-time performance of the system. Sensor technologies are continuously improved to increase the accuracy and frequency of data acquisition.For example, LIDAR technology is improved to obtain denser point cloud data to improve accurate perception of the environment (Hu et al 2022). It is also crucial for computer vision algorithms to be optimized to speed up image processing and ensure that the system can make accurate decisions promptly. Multi-sensor fusion technology is also a research hotspot, while utilizing different types of sensors, the system is able to obtain more comprehensive and multi-dimensional environmental information, improve the accurate perception of the road situation, and reduce the dependence on a single sensor, thus enhancing the robustness of the whole system. Optimization in terms of digital stability has already been introduced with some key techniques. The text will explore two applications to optimize the simulation speed and numerical stability further.

Matlab is a powerful visual programming language. The simulation of robotic work in the Matlab environment is a critical and complex task, in particular the construction of a 3D simulation model of robot kinematics through the Matlab Toolbox V9.10, which allows not only forward and inverse kinematics simulation, but also trajectory planning (Lu et al 2017). The core objective of this work is to gain an in-depth understanding of the changing rules of the angles, velocities and accelerations of the robot's various joints, to provide experimental analysis means and theoretical support for the later development and Research of the robot.

The Simulink toolbox became integral to this simulation process because it allows users to run simulations to model system behavior and perform parameter tuning and optimization. However, slow simulation speed and numerical stability issues are common problems in Matlab simulations. To counter these problems, one can consider reducing the complexity of the model, including simplifying the model structure to reduce the number of nodes or layers, removing unnecessary features and parameters, and reducing the overall computational complexity. Another approach uses a more efficient numerical integration method. More stable than display methods are implicit methods, but they may also increase computational cost. Alternatively, the use of adaptive step control or higher order numerical methods can improve simulation efficiency while maintaining accuracy. When hardware acceleration is considered, graphics processing units (GPUs) are often suitable for parallel computation, especially for large-scale matrix operations. Transferring computational tasks in simulation to GPUs can take full advantage of their large number of parallel processing units, thus accelerating the entire simulation process.

Matlab simulation plays an important role in industrial robotics applications (Zhang 2007). By building robot models in the simulation environment, researchers can simulate and analyze the performance of robots in various work scenarios. This helps optimize the robot's kinematic performance and provides a reference for task planning in industrial production. Especially in the field of industrial automation, robots are increasingly used in assembly lines, production plants, and other environments. Forward and inverse kinematics simulation of industrial robots is a key link in Matlab simulation.

By simulating the kinematic characteristics of robots, researchers can gain insight into the movement patterns of each joint when the robot is performing a task (Lu et al 2017).This is essential to improve industrial robots' accuracy, efficiency, and safety. Positive kinematics simulation allows the end-effector position to be calculated based on a given joint angle, whereas inverse kinematics simulation allows the determination of the desired joint angle to achieve the desired end-effector attitude. Trajectory planning is another key aspect in industrial robot simulation.

Trajectory planning through Matlab allows the researcher to design the robot's motion path in the workspace. This requires an in-depth understanding of the robot's positive and negative kinematic characteristics to ensure that the designed path meets the specific task requirements. This is especially important for scenarios in industrial automation where complex operations and collaboration are required. Trajectory planning is not only about the efficiency of the robot's motion, but also about the overall effectiveness of the production line.

In Matlab simulation, Simulink's parallel simulation technique provides an effective way to increase simulation speed. By dividing the robot model into multiple parts, the parts can be run in parallel, thus reducing the overall simulation time (Xu 2021). This is especially important for dealing with large-scale robotic systems and complex work scenarios. Overall, the application of Matlab simulation in the field of industrial robotics provides researchers with powerful tools to help better understand the kinematic properties of robotic systems, optimize performance, and improve productivity in real-world applications.

# 5 GROWING TREND

Automation technology is rapidly evolving with the advancement of technology. In the future, automation technology is moving towards integration of robotics, machine learning algorithms and many other areas. The current machine learning techniques mainly concern image recognition, natural language and speech processing. This allows computer systems to mimic and understand human perception and language (Zhang 2006). As the amount of data increases and algorithms are optimized, machine learning systems are able to learn more comprehensively from different domains, covering both structured data such as sensor data and statistical information, and unstructured data such as text, video, and images.

This comprehensive learning acquires more contextual information for machine learning, which is expected to give it a deeper understanding of the nature and complexity of the task. For example, industrial robots are robots with autonomous decision making. Not only can they improve manufacturing efficiency and precision working on production lines, but they are also able to perform tasks in different complex environments that are not just limited to predefined programs. In the future, such autonomous robots will be utilized in various fields of application. In the industrial sector, autonomous robots can flexibly adapt and adjust to the changes brought about by the production environment, thus further improving productivity and quality. In the service sector, home service robots can help the elderly to live at home, provide learning assistance to students, answer questions, and even participate in certain teaching activities. When performing dangerous tasks such as earthquakes and fires, robots are able to enter narrow spaces and high radiation areas to perform search and rescue missions without the physical limitations of human beings, thus reducing potential injuries to human beings.

In addition, the widespread use of IoT technology is a key direction in developing automation. IoT interconnects various devices in a smart home system, such as lighting systems, smart thermostats, and so on. Real-time data is collected to analyze the occupants' living habits, preferences and daily behaviors. It provides a more personalized and comfortable living experience by adjusting the room temperature, lighting and other environmental parameters in advance for the occupants. Lastly, IoT enables efficient connectivity and collaboration between transportation systems, energy management, and other facilities in the city. For example, intelligent transportation systems optimize the control of traffic lights by obtaining real-time data on pedestrians and vehicles, slowing down congestion, improving traffic flow, and analyzing data to predict where and when traffic jams are likely to occur and to take measures in advance.

In summary, technology continues to advance. From comprehensive machine learning to robots with autonomous decision-making, to the widespread use of IoT technology in homes, industries and cities, automation will continue to create a smarter, more comfortable future for us.

# 6 CONCLUSION

This paper aims to explore ways to improve productivity, reduce costs, and achieve sustainable development through in-depth Research on the application of Matlab and Simulink in industrial robot path planning and simulation, as well as the application of the technology in autopilot systems. The research methodology mainly includes the application of machine learning techniques in path planning, the optimization of numerical stability, and the key technology and application of Matlab simulation in industrial robotics.

This paper concludes that offline programming is crucial for improving robot performance and work efficiency, especially when dealing with highly repetitive tasks, and productivity can be further improved by optimizing the execution path. Secondly, introducing machine learning techniques provides the system with stronger learning and adaptation capabilities, and by training in virtual environments, the system is better able to adapt to unknown or dynamic environments, thus accelerating the path planning process. In addition, optimizing digital stability, including sensor data accuracy and system real-time improvement, is crucial to ensure efficient robot operation in complex environments.

In terms of Matlab simulation technology, a 3D simulation model of robot kinematics was constructed using the Simulink toolbox, and forward and inverse kinematics simulation and trajectory planning were utilized to gain insights into the motion laws of each joint of the robot. However, the simulation process faces slow speed and numerical stability problems, and the simulation speed can be effectively improved by simplifying the model structure, adopting efficient numerical integration method and using GPU for hardware acceleration.

Overall, the research in this paper covers industrial robot path planning, simulation technology, and key technology applications in autonomous driving systems. The importance of offline programming, machine learning, and digital stability is emphasized, while Matlab simulation technology provides a powerful tool to gain insight into the kinematic characteristics of robots. As technology advances, automation technology will see broader developments in areas such as robotics integration and machine learning algorithms. By applying more comprehensive machine learning, autonomous decision-making robots and IoT technologies, future automation will be better adapted to the needs of different fields, improve efficiency, optimize production and living environments, and create a brighter, more comfortable future.

# REFERENCES


L. Liu, “Research on path planning and related algorithm of robot in large-scale workpiece measurement based on offline programming technology,” Hunan University ,(2022).

H. Hu, W. Wei, Y. Yan, L. Li, Computer Engineering and Application, **58** (02): 57-77(2022).

Z. Zhao, Z. Zhang, W. Wang, W. Wang, J. Jiang, L. Li, Manufacturing Technology and Machine Tool,(02): 34-39(2023).

F. Fu, M. Miao, W. Wang, J. Jiang, X. Xu, L. Liu, Z. Zhou, Journal of Intelligent Systems,**17** (05): 874-885,(2022).

L. Li, C. Cui, L. Luo, L. Li, Automation in Manufacturing Industry,**44** (07): 7-10 + 38,(2022).

Z. Zhang, Simuink-based virtual reality simulation study of robots, Harbin Engineering University ,(2007).

X. Xu, “Construction of a virtual modeling-based testing system for environment perception algorithms of intelligent driving vehicles,” Hunan University ,(2021).

Z. Zhang, “Robot simulation study and kinematic dynamics analysis,” Jilin University,(2006).

Z. Zhou, L. Li, Automotive Engineer,(05): 55-58,(2018 ).

L. Lu, P. Ping, L. Li, Simulation Study of Articulated Robot Motion using MATLAB Robotic ToolBox, 45(17):60-6281,(2017)