# An Analysis of Robotic Arms Control Strategies

Hanbo Xu

{xuh8@rpi.edu}

Rensselaer Polytechnic Institute, New York 12180, USA

**Abstract.** This paper provides an overview of recent research on robotic arm technology mainly focus on perception and control algorithms. Firstly, the paper introduces vision-based robotic robotic arm systems, describes the integration of visual perception and deep learning technologies that enables robotic arms to detect and interact with objects in complex environments. The paper also reviews control methods based on electromyography (EMG), which make human-robot interaction more intuitive by converting muscle signals into robotic motions. Furthermore, the paper discusses motion planning based on reinforcement learning that enhance autonomy and adaptability of robotic manipulators. Overall, this paper summarizes the current progress in robotic arm research and discusses the advantages and limitations of different technical methods. This study can provide a useful reference for future research on intelligent robotic arm systems.

**Keywords:** Vision based, Artificial Intelligence, Machine Learning, EMG signal control

## 1 Introduction

Robotic arms, also known as robotic manipulators, participate deeply in modern automation systems. With the development of artificial intelligence and Industry 4.0, robotic arms are being applied more widely in manufacturing, agriculture, and personal healthcare. Compared with traditional manual operations, robotic arms can significantly improve efficiency, reduce labor intensity and risk in hazardous environments. For the past decades, robotic arms have already able to fulfill precision grasping, manipulation, assembly, and transportation of objects in repetitive missions in factories.

Besides the extensive use of robotic arms in industrial applications such as production of cars and electronic components, the technology becomes more important in agricultural field. They are expected to improve production efficiency or reduce the impact of the population aging problem[1][2]. The cases prove that the enhanced sensing system and manipulator make the automated fruit harvesting operations in complex orchard environment feasible.

Since the introduction of artificial intelligence (AI) technologies which have made huge progress in recent years, robotic arms are able to work more stable and efficient in variable complex environment. The reinforcement learning (RL) provides better development conditions

ICMEEA 2026, April 24-26, Singapore, Singapore

DOI 10.4108/eai.24-4-2026.2364992

for vision-based control strategies[3]. This technology makes the replacement of labor by using automated robotic manipulator in process that relies on manual judgement a possible direction.

The traditional development area, Inverse Kinematics (IK), is also benefits from the improvement of AI technologies. Compared to old computation method used to solve IK and other motion problem, which could realize precision requirement but difficult to compute, the learning method becomes a better approach to solve the problem [4].

Electromyography (EMG) signal control is a research area that cross over decades. This technical solution usually aimed to work in hazardous environments and personal heath care sectors such as assisting elderly populations and persons with disabilities [5]. EMG signals control algorithm can translate human arm motions into robotic arm movements by reading the signals generated by muscle activities. Different from traditional interface logic that using graphical or other pendants, EMG control provides a more intuitive and flexible solution.

Although significant progress has been made in robotic arm technology, several limitations still remain. Some of the robotic systems still rely seriously on predefined models or structured environments, which means their adaptability when operating in complex or unstructured scenarios were not been fully proved. While the vision-based perception systems could operate efficiently and precisely, they still have problems of environmental factors disturbance, such as lighting variations, occlusions, or sensor noise. In addition, motion planning algorithms must balance efficiency and safety when generating motion trajectories in environments containing obstacles. These challenges indicate that robotic manipulators still require further improvements in anti-interference capability, sensing accuracy, control flexibility, and adaptability in different environments[6-8].

Based on these issues, this study focuses on the analysis and review of developments trending and applications improvement in robotic arm technologies.

## 2 Vision-Based Robotic Arms

Vision-based robotic arms have become an important research direction in recent years. The technology has already been proven effective in intelligent vehicles, which enable the systems to better perceive and respond to the environment. By integrating cameras, computer vision algorithms, and reinforcement learning, robotic arms can detect objects, locate the precise positions, and complete manipulation tasks autonomously. Compared with traditional industrial robotic arms that operate in predefined environments and moves rely on preset routes, vision-based systems allow robotic arms to perform tasks more flexibly.

The first case that investigated this strategy is the dual-arm fruit harvesting robot developed by Yoshida et al. [1]. In order to replace the manual labor required with an automated process to perform tasks involve fruit picking in a traditional agricultural environment. The robot is equipped with multiple RGB-D cameras that capture both color and depth information. Using a deep learning–based object detection method, the system identifies fruits in images and estimates their three-dimensional positions. At the same time the target fruits are detected, inverse kinematics and path planning algorithms are applied to ensure the robotic arms can move toward the fruit without collisions with their surrounding.

The key innovations of this work are the integration of multi-camera 3D-space perception with a coordinated dual-arm robotic structure, and the collaboration of IK and route planning. The camera system helped reducing blind spots caused by leaves and branches occlusions, while the dual-arm design improved harvesting efficiency by simultaneous manipulation at different positions. The combination of IK and motion planning avoided the robotic arms colliding with fruits. The experimental results of this research showed that the robot was capable of detecting and harvesting fruits include apples and pears without collisions in complex orchard environments. This study indicates that combining visual perception with robotic manipulators can replace traditional human labors with automated process in agricultural tasks[9][10].

Another research explored the use of deep learning technology for vision-based robotic arm control. In the vision-based robotic arm control algorithm proposed by Sekkat, H., Tigani, S., Saadane, R., and Chehri, A.[2], camera images are used as the main input for object detection and positioning. A deep neural network processes visual information to identify target objects in the scene. Thus, the system can estimate the spatial position of the detected object and generate corresponding motion commands for the robotic arm. This allows the robot to perform manipulation tasks based on visual information.

The primary innovation of this method is the use of deep learning models to improve visual perception ability and system adaptability. Compared with traditional robotic arm systems that rely on manually designed features for object detection, which have worse stability in complex environments due to lower anti-interference capability. By using deep neural networks, the system can learn visual features from image samples, improving its ability to recognize objects under different conditions.

Experimental evaluations showed that the vision-based control framework can guide robotic arms to interact with objects accurately using visual input. This case proved the better ability to adapt to variations in object appearance and that under different environments.

Despite these advantages, several challenges remain for vision-based strategies. Some unexpected environmental factors involves lighting variations, occlusions, and complex backgrounds can reduce detection accuracy or even cause the system to misjudge.

## 3 EMG Signal Control

This section discusses a case of motion planning that use learning method. Traditional motion planning algorithms typically use predefined mathematical models to calculate the trajectories. Though these kinds of strategies have been proven able to generate feasible movement routes in structured environments and have been applied in industries, their performance is often largely affected in complex or dynamic conditions. As machine learning emerged, many researchers integrated this technique into robotic arms control to increase their efficiency and adaptability in different conditions. Human-robot interaction has become an important research topic. One approach is the use of EMG signals, which measure electrical activity generated by human muscle motions. EMG-based control enables robotic manipulators to read human motion intentions directly from muscle activity, users can operate robotic arms in a more natural and intuitive way.

In the system designed by Gowtham, S., Krishna, K. A., Srinivas, T., Raj, R. P., and Joshuva, A.[5], EMG sensors are used to collect electrical signals from the muscles of the human forearm. These signals from muscles are converted to corresponding motion commands that control the movement of the robotic arm. The system also integrated an accelerometer as an implement to detect postures and gestures. For the experimental results, the robotic manipulator successfully performed basic motion tasks include positioning and object manipulation, based on signals collected from the user.

Earlier studies have also investigated EMG-based robotic control. For example, Artemiadis and Kyriakopoulos proposed a robotic arm control framework based on low-dimensional embeddings of EMG signals [4]. In this approach, electromyographic signals recorded from multiple upper limb muscles are analyzed using dimensionality reduction methods to capture underlying muscle synergies. The high-dimensional EMG signals are transformed into a low-dimensional representation that reflects coordinated muscle activations during arm movements. In the experiments, users could control a robotic arm in real time and perform simple movements in three-dimensional space.

The low-dimensional embedding approach successfully lower the computation difficulty and performed smooth movement. Compared with the second case, the first one reduced the noise, and realized more complicated movement with the extra accelerometer as an implementation.

In addition to these advancements, EMG-based control systems still face several challenges. Muscle signals may still be affected by noise, and differences between individual users that reduce accuracy. As a result, many EMG-based systems still require additional sensing methods, more advanced noise reduction method, or integrating learning method to improve performance.

Overall, EMG-based control could be a reliable direction to developing an intuitive human-robot interaction control method. By translating human muscle motions into robotic motion commands, these systems can realize more natural and efficient control of robotic arms. At the same time, further improvements in signal processing methods, adaptive algorithms, and sensor reliability are necessary to enhance the stability and practicality of EMG-based robotic control systems in real-world applications.

## 4 Learning-Based Motion Planning

This section discusses a case of motion planning that use learning method. Traditional motion planning algorithms typically use predefined mathematical models to calculate the trajectories. Though this kind of strategies were proved able to generate feasible movement routes in structured environments and has been applied in industries, their performance often largely affected in complex or dynamic conditions. As machine learning emerged, many researches integrated this technique into robotic arms control to increase their efficiency and adaptability in different conditions.

In recent years, advancements in artificial intelligence have introduced deep learning and reinforcement learning techniques into the field of robotic control strategies. These methods allow robotic systems to optimize control performance by interacting with the environment rather than relying solely on manually designed models. One research on this approach is the deep reinforcement learning framework designed for autonomous obstacle avoidance in robotic arm motion planning [5]. In this study, a reinforcement learning algorithm is used to train a robotic manipulator to generate collision-free trajectories while moving toward a target position.

In this approach, the robotic arm and its surrounding environment are treated as a learning environment. The robot interacts with this environment and receives feedback based on the actions it performs. During the training process, the robotic arm explores different motion strategies while receiving reward signals that encourage reaching the target efficiently and avoiding obstacles. The learning algorithm improves the control policy and enables the robot to generate safe and efficient motion trajectories over time. Experimental results show that the trained robot successfully moved autonomously and avoided obstacles while maintaining stable movement toward the target in complex environments.

The main point of this method is the integration of deep reinforcement learning with robotic motion planning. Difference to traditional trajectory planning methods that require explicit modeling of the environment, the learning-based approach allows the robot to acquire motion strategies through experience. This capability improves the adaptability of robotic manipulators, particularly in environments where obstacles or workspace conditions may change. The experimental results demonstrate that reinforcement learning can effectively enhance the autonomy of robotic arms by enabling them to learn optimal motion behaviors through repeated interactions with the environment.

Learning-based training methods are frequently integrated with other control method which represents a main direction in developing robotic systems. By combining reinforcement learning with advanced perception and control techniques, robotic manipulators have higher potential to achieve better autonomy, reliability and adaptability in complex environments. Future efforts in this field is expected in order to further improve the efficiency and reliability of learning-based robotic motion planning methods. Hence the application of robotic arms could be wider and not limited to industry use.

## 5 Conclusion

Robotic arms have become an essential component of modern automation systems, with increasingly widespread applications in industrial production, agriculture, and personal healthcare. This review has discussed several key technological developments in robotic arm research, including vision-based manipulation, EMG-based human–robot interaction, and learning-based motion planning methods. These researches demonstrate that the developing direction of robotic manipulators evolves from traditional preprogrammed machines into more intelligent systems.

Vision-based manipulation systems have significantly improved the adaptability of robotic arms to operate in unstructured environments and ability to recognize objects by integrating camera systems and machine learning algorithms. These technologies enable robots to detect objects and plan operations based on visual perceptions. At the same time, EMG-based control methods represent a feasible direction of human–robot interaction, which robotic manipulators are controlled directly by human movements. Such approaches provide a possibility for assistive robotics for personal healthcare and tasks in hazardous environments. In addition, learning-based methods, such as deep reinforcement learning, have a basement for autonomous robot control.

Besides these advances, challenges still remain in the development of robotic arm systems. The reliability of vision-based method should be considered in complex conditions such as lighting changes or object occlusion. For EMG-based control systems, signal noise and differences between users are still crucial problems, which may reduce control accuracy.

Further research is expected to focus on the integration of sensing method, control, and learning algorithms to enhance the efficiency, adaptability and robustness of robotic manipulators. The combination of advanced sensing technologies, artificial intelligence, and human–robot interaction techniques will make the autonomous or human controlled robotics work more efficiently with higher reliability. With future technological development, robotic arms will be increasingly important in industrial, agricultural automation, healthcare assistance, and even more uncleared fields.

## References


[1] Yoshida, T., Onishi, Y., Kawahara, T., and Fukao, T.: Automated harvesting by a dual-arm fruit harvesting robot. ROBOMECH Journal. vol. 9, no. 1, p. 19 (2022)

[2] Sekkat, H., Tigani, S., Saadane, R., and Chehri, A.: Vision-based robotic arm control algorithm using deep reinforcement learning for autonomous objects grasping. Applied Sciences. vol. 11, no. 17, p. 7917 (2021)

[3] Wu, Q., Zhao, H., Chen, X., and Zhao, Y.: Review of technology, application status and development trend in multi-arm cooperative robots. Journal of Mechanical Engineering. vol. 59, no. 15, pp. 1–16 (2023)

[4] Calzada-Garcia, A., Victores, J. G., Naranjo-Campos, F. J., and Balaguer, C.: A review on inverse kinematics, control and planning for robotic manipulators with and without obstacles via deep neural networks. Algorithms. vol. 18, no. 1, p. 23 (2025)

[5] Gowtham, S., Krishna, K. A., Srinivas, T., Raj, R. P., and Joshuva, A.: EMG-based control of a 5 DOF robotic manipulator. In: 2020 International Conference on Wireless Communications Signal Processing and Networking (WiSPNET), pp. 52–57. IEEE (2020)

[6] Artemiadis, P. K., and Kyriakopoulos, K. J.: EMG-based control of a robot arm using low-dimensional embeddings. IEEE Transactions on Robotics. vol. 26, no. 2, pp. 393–398 (2010)

[7] Yang, S., and Wang, Q.: Robotic arm motion planning with autonomous obstacle avoidance based on deep reinforcement learning. In: 2022 41st Chinese Control Conference (CCC), pp. 3692–3697. IEEE (2022)

[8] Babu Loganathan, G.: Implementing industrial robotics arms for material holding process in industries. Journal of Harbin Institute of Technology. vol. 53, no. 9 (2021)

[9] Jin, T., and Han, X.: Robotic arms in precision agriculture: A comprehensive review of the technologies, applications, challenges, and future prospects. Computers and Electronics in Agriculture. vol. 221, p. 108938 (2024)

[10] Muehlhaus, M., Koelle, M., Saberpour, A., and Steimle, J.: I need a third arm! Eliciting body-based interactions with a wearable robotic arm. In: Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems, pp. 1–15. ACM (2023)