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Review Article

Common Challenges in Control of Industrial Manipulators: A Review

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Abstract

Robotic manipulators are extremely nonlinear complex and uncertain systems. Robotic manipulators have wide applications in areas like process, medicine, healthcare, automation, agriculture, research and education, automobile, military and space etc. Effective control of these manipulators is extremely important to perform these industrial tasks. Parameter uncertainties, disturbances, and nonlinearities make it very difficult to control the robot manipulator. Researchers are working on the control of robotic manipulators using conventional and intelligent control methods. Conventional control methods are proportional integral and derivative (PID), Fractional order proportional integral and derivative (FOPID), sliding mode control(SMC), and optimal and robust control while intelligent control method includes Artificial Neural networks (ANN), Fuzzy logic control (FLC), and metaheuristic optimization algorithms. There are four main challenges for any robot system development as robotics systems required multidomain expertise, end-to-end workflow, algorithm complexity, Technical depth, and system stability. This article provides the overall view on industrial robotics systems development.

Keywords: Robotic manipulators; Metaheuristic algorithms; System stability; Control System

Introduction

The study of the nonlinear control of manipulators is increasing day by day for scientific investigation and industrial purposes [1]. Robotics is a multidisciplinary system branch that requires multi-domain expertise. The control of a robot manipulator is the most challenging task as even a single link manipulator is nonlinear in nature and has highly complex dynamic behavior [2]. There are many nonlinear control approaches like SMC, robust control, adaptive control, and intelligent control [3-5]. With the development of computational power, the use of AI-enabled robotics is increasing day by day.

Mostly Robots work on the architecture of SPA (Sense, Plan, Act). Sense means to sense their surroundings, such as the presence of barriers, Plan means the robot needs a strategy to do some task in that sensed environment, Act means once a strategy for completing the objective has been devised, the robot must carry out the strategy's instructions.

The design of any robotic system needs the knowledge of kinematic and dynamic analysis, mathematical modelling, control system, image processing, simultaneous localization and mapping (SLAM), sensor interface and communication system, embedded system, hardware interface, real-time operating system, optimization of different parameters etc. The Autonomous industrial robotics system workflow is as shown in Figure 1.

Robotics systems required multidomain expertise, end-to-end workflow, algorithm complexity, technical depth and system stability. Safety standards given by ANSI R15.06-1999, offers instructions for the construction and integration of industrial robots and robot systems with a focus on their secure use, the significance of risk assessment, and ensuring worker safety.

Control Methods

The control of robots can be done using various techniques such as model-based control, rule-based systems, feedback control, or hybrid approaches that combine multiple methods. In the literature, there is n -number of controllers and nonlinear control techniques available but implementing them in real-time is still far away. Robotic manipulator plays an important role in the industry in increasing quality and productivity if the overall process as a manipulator has greater flexibility than normal machines. In the design of a robot manipulator, different control strategies are designed according to different task requirements such that desired result can be obtained. The main objectives of control are stability, tracking, and performance Index. The stability of a robot can be affected by various factors, such as the robot's configuration, its weight distribution, the forces acting on it, and the type of task it is performing. The stability analysis of robots is often based on Lyapunov's stability theory, which provides a systematic method for determining the stability of a system. To get the desired performance of the system several control schemes including PID, FOPID, adaptive, optimal, backstepping, Intelligent control, Robust, and SMC have been implemented. SMC guarantees trajectory tracking with a rapid response for the robotic manipulators. SMC is well recognized as a robust control for dealing with uncertainty in nonlinear systems. Although SMC gives a robust response, it yields a chattering effect that can cause instability in the controlled system [6]. The high value of controller gains excites the high-frequency dynamics that create chattering. Boundary layer methods suggest the use of sigmoid function, saturation function, and use of fuzzy logic. These approaches reduce chattering since they function as low-pass filters. Unknown control direction can manifest intensified problems for the manipulators. It is referred to as the wrong connection between actuators and drivers, researchers are finding ways to overcome this.

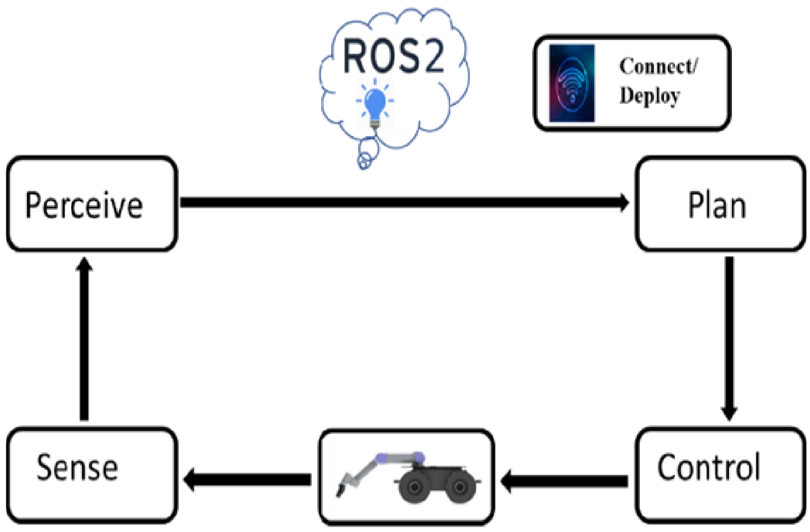

Figure 1: Model-based robot design workflow.

In the case of AI–enabled robot machine learning control and Data-driven control approaches are most suitable when we have large data sets to predict future behavior Metaheuristic approaches like Whale optimization algorithms (WAO), Multiverse optimization (MVO), moth flame optimization (MFO), and grey wolf optimization (GWO) to control the trajectory of the manipulator.

Conclusion

The mentioned control methods given in the paper are useful for achieving the desired task. control is used to predict the boundaries of uncertainty and external disturbances. Furthermore, the suggested control removed the chattering phenomena while maintaining robustness and accuracy.

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Conflict of Interest

No conflict of interest.

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