


Chapter 9


Intelligent Control Systems for Smart Industrial Automation and Robotics

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ABSTRACT

Intelligent Control Systems (ICS) are transforming industrial automation and robotics by enhancing precision, efficiency, and adaptability. By leveraging machine learning, adaptive control, and real-time sensor feedback, ICS optimizes tasks like assembly, welding, and quality inspection. These systems boost productivity, improve product quality, and enhance workplace safety while reducing costs and errors. Despite challenges such as complexity, integration issues, and high initial costs, solutions like modular designs, user-friendly programming, and Robotics-as-a-Service (RaaS) are accelerating adoption. This chapter explores the role of ICS in smart manufacturing, highlighting key applications, benefits, challenges, and

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1. INTRODUCTION

Over the last hundred years, manufacturing has seen dramatic shifts, moving away from manual processes that rely heavily on human labour and towards systems that are incredibly automated and technologically sophisticated. This change has been brought about by the dogged quest for accuracy, efficiency, and productivity, which has allowed businesses to maximise output while decreasing mistakes and improving overall operational effectiveness. The implementation of industrial robotics has been a driving factor in this shift, since it has altered production methods and is still reshaping the sector thanks to innovative technology (M.N.O. Sadiku, 2018).

Industrial robotics can trace its roots to the first industrial robot, Unimate, which was introduced in the early 1960s and was instrumental in automating assembly lines for automobiles. As a result of this innovation, robotic capabilities have been steadily expanding throughout many different industries, igniting a technological revolution (Groover, M. P. (2013). Constant technical development, rising consumer demand, and the desire for more efficient production have all contributed to the gradual but steady rise of robots in industry over the past few decades. The capabilities and applications of industrial robots have been greatly enhanced by advancements like AI-driven automation, robotic vision systems, and programmable logic controllers (PLCs) (Fu, G, 2020). But conventional robotic control methods, including PLCs and pre-programmed automation, can't keep up with the ever-changing demands of today's manufacturing processes (Craig, J. J. 2009). Intelligent control systems are in high demand because they improve robotic performance in dynamic and fast-paced manufacturing environments through facilitating improved automation, real-time decision-making, and flexibility (Y. Devarajan, 2018). By replacing static, pre-programmed processes with dynamic, self-learning ones, intelligent control systems herald a sea change in industrial automation (Siciliano & Khatib, 2008). These systems use AI, machine learning algorithms, and sophisticated computational models to give robots the ability to analyse data in real-time, adjust to changing manufacturing conditions without human input, increase the variety of tasks they can do, and improve their predictive maintenance capabilities, which in turn reduces downtime and improves operational sustainability (J. Fan, 1980).

Manufacturers have been able to optimise resource utilisation, minimise errors, increase product quality, and expedite operations thanks to the integration of intelligent control systems into industrial robots. This integration has led to several breakthroughs (Pires, J. N. 2007; Schultz, U.P., 2020). These control systems enable robots to carry out complicated tasks with little to no human oversight, creating a

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