Chapter 2
The Usefulness of Digital Twin in Manipulator Robot Control

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ABSTRACT

Digital twin (DT) plays a key role in smart industry by being one of the most useful technologies which has the ability to attach the physical space with the cyber space. On the other side of the coin, manipulator robots have also played an essential role in industrial processes, especially that robots are embedded with sensors and actuators that can lead to a smart control. In this study, generalities about digital twin are mentioned; moreover, the relationship between digital twin and the control of manipulator robots is explained step by step. A simulation study has been employed to the universal robot UR10 applying the sliding mode control. This project shows that the cyber space is beneficial for creating a simulated smart industry by observing real-time state of the process, testing different decisions in simulation before performing the required actions directly in the real system, and acting with different situations.

1. INTRODUCTION

For the first time, the notion of Digital Twin was suggested by Professor M. Grieves of the University of Michigan in 2003 (Grieves 2016). Then, it started attracting more attention by the end of 2011, when technology knew a rapid growth, specifically by the evolution of simulation technologies, internet of things, big data, sensor innovations, etc. In 2012, NASA considered the usefulness of the implementation

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of digital twin to improve the performance of air force vehicles (Glaessgen and Stargel 2012). Two years later, Digital Twin was no longer just a theoretical idea, but moved into reality in some manufactories (Grieves 2014). Currently, the reason which has further encouraged the improvement of digital twin is that this concept not only restricted to the aerospace industry, but can be used in many different fields (Tao et al. 2019). In 2025, Gartner predicts that 25 enterprises using Digital Twin will earn 1$ billion in revenue and in 2027, Gartner also estimates that 40 percent of the companies over the world will be using Digital Twin (Attaran and Celik 2023).

Digital Twin was given different definitions in several articles. Generally, it defines the relation between the physical and virtual objects. Depending on the type of the digital Twin, the cyber simulation space represents and reflects the physical space based on constant transmission data and real-time sensor data and it can trigger or observe the functioning of the physical world containing real devices (Negri et al. 2020). Consequently, this technology leads to improve performance and processes of industries and also allows the quick detection of physical problems which will facilitate finding solutions (Attaran and Celik 2023). Moreover, manipulator robots are commonly used in many industries to accomplish different tasks especially the more complexed ones. Hence, it is undeniable that they play a key role in their process. Therefore, starting to employ the digital twin concept to control the manipulator robots will have a great advantage in the improvement of many industries. Nowadays, many researches employ digital twin in robotic field. As an example, in the article (Matulis & Harvey 2021), the authors used digital twin to train a robot arm with reinforcement learning in the cyber space to complete a desired task and finally apply this training in the physical space. However, there is a limited number of writings using the robot operating system software with digital twin to control robots.

Manipulator robots are typical nonlinear and time varying dynamical systems. Therefore, the conventional linear control strategies are not satisfying the control of these robots. In literature, there are many conventional nonlinear methods to control manipulator robots such as feedback linearization (Deluca 1988), force control (Mason 1981), Sliding Mode Control (Slotine & Li 1991), backstepping (H.-J. Shieh and C.-H.Hsu, 2008), etc. However, some of these methods aren't robust enough to unexpected disturbances or to uncertainties (Kali et al. 2016). Yet, since 1980, the theory of the sliding mode control has been acknowledged by its practical simplicity and its robustness which is opposed to the uncertainties, disturbances and the variations of parameters (Slotine & Li 1991). Despite those advantages, the fundamental disadvantage of this approach relates to the chatter phenomenon due to high-frequency oscillations near to the sliding surface S used in the controller with a switching function Signum. To reduce the problem of chattering with the same precision and performance, there are several functions that can be used such as saturation function that will be applied in this study (Ömür 2021).

The goal of this chapter is to prove that using digital twin in the control of manipulator robot would obviously be of great benefit in the improvement of smart industries. It will lead to develop optimal solutions through simulation in virtual world and optimal manufacturing by increasing product quality, stability and accuracy. It will induce to high durability of the physical components by predictive diagnosis and analytical assessment. For instance, in case of faults in the robot manipulator, Digital Twin can be used to detect those faults by data analysis and monitoring (Omali et al. 2021). Nevertheless, controlling robot manipulators poses different challenges by using Digital Twin. The main challenges to discuss afterwards are about the representation of the robot manipulator in the digital space and how to manage communication, data analysis and simulation of two sliding mode control methods.