Chapter 14
Virtual Intelligent Autonomous Agents: Robot Navigation for Disaster Intervention

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ABSTRACT

The intersection of Artificial Intelligence (AI) and robotics has helped to promote the idea of enhancing the performance of real-world autonomous systems through their digital twins. In this context, reinforcement learning (RL) emerges as a key technology used by digital twins in learning policies that results in enhanced performances. RL problems are typically modelled within the Markov Decision Process (MDP) framework, where an agent learns to take actions in a stochastic environment to maximize rewards. A scenario where an intervention robot has to be trained to detect and navigate to a gas pipe leakage while avoiding collisions with objects on in its path was considered and simulated in this chapter. The robot was trained using the Unity platform which was selected mainly due to its support for RL and its realistic physics simulation engine. Simulation experiments revealed that the minimum steps it takes the robot to master the task was around 300,000 steps. After this, the robot intelligently navigated to the gas leakage by following the shortest path while avoiding collisions.

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INTRODUCTION

Agent-based problem-solving makes it possible to tackle complicated problems in remote and heterogeneous environments by breaking them down into smaller, easier-to-solve problems (Rodriguez-Arias et al., 2020). According to Wooldridge (2009), an intelligent agent is a computer system that can detect changes in its environment and react correctly and autonomously. In addition, an agent must be resilient (able to recover from errors), socially proficient (able to interact with other agents), and display both proactive and reactive actions (Padgham & Winikoff, 2004).

The proliferation of autonomous agents such as self-driving vehicles, robots, etc. in diverse sectors has necessitated a paradigm shift in their development from the usual engineering-centric approach that involves explicitly programming a system to perform tasks to a data-centric approach where agents are made to learn how to perform tasks through extensive data (Rasheed et al., 2024; Tian et al., 2023). The transition to the data-driven approach has made the "digital twins" or virtual clones an important component in the developmental process.

A digital twin is a digital representation (software) that mimics the operational state of a physical system (hardware)(Bilberg & Malik, 2019; Kousi et al., 2021; Li et al., 2021; Lv et al., 2021; Pérez et al., 2020; Schleich et al., 2017; Vlădăreanu et al., 2020). In other words, the digital twin resides on a computer system and it may be regarded as a digital object since it is the digital equivalent of a physical object. In his University of Michigan course in 2002, Professor Grieves (Zong et al., 2021) made the first proposal for digital twin technology. This idea is significant because it recognizes the feedback that exists between the virtual and physical worlds. Its primary uses were to monitor and forecast the spacecraft's early flight condition, as well as to mimic and analyze spacecraft in flight. Over the last 2 decades, this technology has advanced quickly and found widespread use in a variety of different industries, including smart cities, automobiles, ships, power plants, robotics, complicated electromechanical equipment, and medical care to mention a few.

The digital twin concept has played a major role in the convergence of artificial intelligence (AI) (Roy et al., 2019; Sano et al., 2021; Vernon, 2019; Yang et al., 2020) and robotics. Many people mistakenly believe that AI and robots are interchangeable. Robots are often defined as physical machines with sensors and actuators that may or may not need intelligence to carry out certain tasks; artificial intelligence, on the other hand, is a program and does not need physicality. However, as robots are physical beings, advancements in robotics open up new avenues for the integration of AI since these machines can see, act upon, and shape their surroundings as well as engage socially. However, AI gives machines the ability to develop and learn. It makes sense why AI and robots are becoming more and more entwined to yield

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