Chapter 4
Enterprise Digital Twin:
An Approach to Construct Digital Twin for Complex Enterprises

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ABSTRACT

Enterprises constantly aim to maximise their objectives while operating in a competitive and dynamic environment. This necessitates an enterprise to be efficient, adaptive, and amenable for transformation. However, understanding a complex enterprise and identifying effective control measure, adaptation choice, or transformation option to realise specific objective is not a trivial task. The digital twin that imitates the real enterprise provides an environment to conduct the necessary interrogative and predictive analyses to evaluate various control measures, adaptation choices, and transformation options in a safe and cost-effective manner without compromising the analysis precision. This chapter reflects on the core concept of the digital twin, evaluates the state-of-the-art modelling and analysis technologies, and presents a pragmatic approach to develop high-fidelity digital twin for large complex enterprises.

INTRODUCTION

A digital twin is a comprehensive and machine-interpretable description of components, behaviours and operation of real systems, processes and products (henceforth they are referred as *systems*) for a range of interrogative and predictive analyses that lead to decision making (Grieves, 2012). Industry is now increasingly witnessing the economic significance of such *digital twins* for controlling, adapting and designing a wide range of complex systems (Grieves and Vickers, 2017). An effective digital twin helps to expedite the time to market and reduce the cost of system development by analysing the consequences of the prospective control, adaptation and design choices prior to their implementations in reality.

The core concept of digital twin is effectively adopted in engineering disciplines (Schleich et al., 2017) and mission critical systems (Glaessgen and Stargel, 2012). They develop high-fidelity physics and mathematical models to represent system behaviours to enable analytical simulation for understanding

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system behaviour and evaluating the efficacy of various hypothetical changes with respect to specific system goals. The key objective for constructing such digital twins is to reduce or eliminate real-life experiments, which are often expensive and infeasible. While the benefits of a digital twin over controlled experiments are well established in engineering disciplines, its utilisation is not yet in mainstream practice for business enterprises, such as supply chain, telecom, business process outsourcing organisation and software service provisioning. State of the practice of interrogating and predicting business enterprises are still chiefly driven by the intuitions of human experts.

This chapter discusses the core concept of conventional digital twin, explicates the necessary aspects and characteristics that needs to be considered for conceptualising digital twins of modern business enterprises, and reviews the existing modelling and simulation techniques that are relevant for constructing digital twins for such business enterprises. It also discusses an *actor* (Agha, 1966a, Hewitt and Smith, 1975) based bottom-up approach along with relevant verification and validation techniques for constructing faithful digital twins to support evidence-driven informed decision making for business enterprises.

BACKGROUND

The core concept of digital twin of enterprises is traced back to *Information Mirroring Model* published in 2005 (Grieves, 2005). This primitive model is refined multiple times to support complex systems and termed as digital twin in *Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management* (Grieves 2011). Over the years, the efficacy of the digital twin are demonstrated using various state-of-the-art modelling paradigms, simulation technologies, Internet of Things (IoT), sensor technologies and a wide range of data analytics techniques. The utility of a digital twin is established in several engineering disciplines. For example, the concept has been widely adopted in several astronautics and aerospace researches since NASA has included it in their technology roadmap (Glaessgen and Stargel, 2012).

Conceptually such digital twin is formed using three core elements: (i) real environment, (ii) virtual environment and (iii) connection between two environments as shown in Figure 1. The real environment is an actual enterprise, system, product or process. The virtual environment is a faithful representation of the real environment. A virtual environment is typically formed for a range of in-silico interrogative and/or predictive analysis, where the key objectives are: (a) understand current system in precise form, (b) analyse the efficacy of hypothetical changes or adaptation strategies to realise specific goals of a real environment, and (c) explore design alternatives of a new environment.

The virtual environment in a digital twin is connected with a real environment using two-way connections as shown in Figure 1. The information link from real environment to virtual environment serves two purposes: (i) provides necessary information about the real environment, which help to construct a virtual environment and ensure its faithfulness, and (ii) supplies system data to set the state of a virtual environment same as a real environment. The information that helps to construct a model of a real environment and establish the model validity is necessary at the construction phase of a digital twin. The data flow that contains information about the state change of a real system is a periodic/continuous information flow that keeps a virtual environment up-to-date with respect to a real environment. This enables in-silico simulation driven analysis of enterprise. The reverse information link, *i.e.*, information link from virtual environment to real environment, communicates the effective control instructions and change recommendations that include the change in structure, behaviours and/or goal of a real environ-

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