Towards Digital Twins Cloud Platform:

Microservices and Computational Workflows to Rule a Smart Factory

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ABSTRACT

The concept of "Industry 4.0" considers smart factories as data-driven and knowledge enabled enterprise intelligence. In such kind of factory, manufacturing processes and final products are accompanied by virtual models – Digital Twins. To support Digital Twins concept, a simulation model for each process or system should be implemented as independent computational service. The only way to implement an orchestration of a set of independent services and provide scalability for simulation is to use a cloud computing platform as a provider of the computing infrastructure. In this paper, we describe a Digital Twin-as-a-Service (DTaaS) model for simulation and prediction of industrial processes using Digital Twins.

CCS CONCEPTS

• **Information systems → Web services**; • **Computer systems organization → Cloud computing**;

KEYWORDS

cloud computing, container-as-a-service, Digital Twin, smart manufacturing, software-as-a-service, platform-as-a-service, digital twin-as-a-service, workflow, microservice, Industry 4.0

1 INTRODUCTION

The smart manufacturing concept is now one of the main development trends in the industry. One of the key approaches to this concept is a "Digital Twin" concept. *The Digital Twin (DT)* supports virtual models of real equipment, industrial process, and final products. The Digital Twin provides methods of analysis of data from diverse types of sensors installed on the objects for tuning and actualization of their virtual state. The DT applies different mathematical models for simulation of the processes of interest that are implemented using statistical methods, data mining, and finite element method, etc.

To develop a DT of an industrial process or equipment, we can present it as a computational workflow composed of a set of computational services that represent models for process stages and their interaction [3]. Each of these computing methods defines specific requirements for the necessary computational resources. One of the possible solutions that provide high flexibility on the one hand, and high computing performance on the other hand, is to use containerization technology [1]. Thus, it is needed to provide a cloud system that uses "Container-as-a-Service" model, that would support the Digital Twin execution. In this paper, we describe a model of the Digital Twins Cloud Platform for simulation of industrial processes in the form of workflows.

2 THE DIGITAL TWIN

The Digital Twin is a hierarchical system of mathematical models, computational methods and software services, which provides near real-time synchronization between the state of the real-world process or system and its virtual copy. We can highlight a Distributed Virtual Test-Bed (DiVTB) [4] technology that provides a simulation of industrial process and systems based on data provided by end-user, as one of the predecessors of the Digital Twin concept. Up to now, the difficulty of near real-time data harvesting from the objects of interest has been the main obstacle to the broad application of the DT technology. Using this data and analysis methods, we can design the Digital Twins of smart factory's industrial processes and sophisticated end-products. The following characteristics of the DT can be highlighted:

- *Real-time reflection.* A DT is a reflection of a physical object (equipment, process or system) that keeps ultra-high synchronization and fidelity with the real-world [2].
- *Hierarchy.* A DT of an industrial process can contain DTs of the process stages, which, in turn, contain DTs of the equipment enforcing these stages.
- *Self-evolution.* Since a DT provides a reflection of the object or process, it should perform undergoing continuous model

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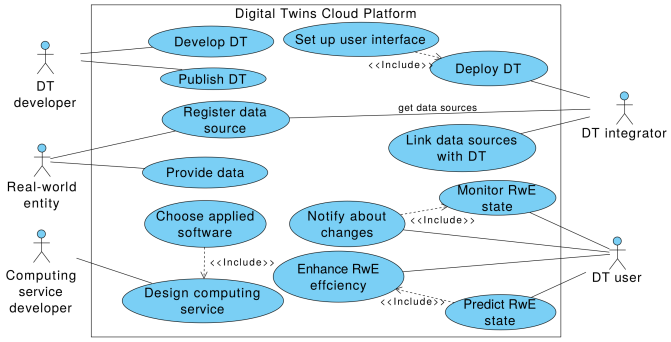

Figure 1: Digital Twins Cloud Platform use-cases

improvement through comparing the simulation process with physical object or process, concurrently.

- *Flexibiliy.* The DT uses diverse types of models to simulate a real object's current state. The comprehensive and well-timed state reflection can be obtained only by usage of models with the accuracy, necessary and sufficient for satisfying the "real-time reflection" requirement.

3 THE CONCEPT OF THE DIGITAL TWIN CLOUD PLATFROM

To provide the DT execution, we design a Digital Twins Cloud Platform, which provides a dynamic allocation of computing resources and provides an API to present the DTs as a microservices. Thus, DTs Cloud Platform provides a "Digital Twin-as-a-Service" (DTaaS) cloud model. The DTaaS model presents the DT as a set of cloud services to store and to analyse the data gathered from sensors, simulation of the real-world objects, and their visualization of the virtual representation.

The DTs Cloud Platform provides the following levels of abstraction:

(1) *The level of the Digital Twin user.* On this level, the user can get an access to the available DTs in the form of cloud applications based on the "Software-as-a-Service" model.
(2) *The level of the Digital Twin developer.* At this level, the cloud platform provides resources for the development of DTs based on a "Platform-as-a-Service" model. A DT is described as a computational workflow, the nodes of which correspond to the Computing Services and other DTs, while links correspond to the data flow between nodes.
(3) *The level of the Computing Service developer.* At this level, the cloud platform provides an API for Computing Service development based on a "Backend-as-a-Service" model. A Computing Service is represented as a microservice responsible for specific data processing operation or execution of a specific set of computational methods.
(4) *The level of the cloud infrastructure provider.* At this level, instances of Computing Services are mapped to the cloud computing resources provided by the cloud platform based on "Container-as-a-Service" model.

We can define the following main actors, who interact with the DTs Cloud Platform (see Fig. 1).

(1) *Digital Twin user* utilize DTs to get the necessary information about real-world entities, such as their status, notification about real-world entity state changes, prediction of their behavior and parameters under certain conditions, recommendations of the enchantment of real-world entity efficiency, etc.
(2) *Digital Twin integrator* is responsible for the deployment of DTs on industrial objects through a connection of real-world entities with their virtual representation, setting up and provision of DT user interfaces.
(3) *Digital Twin developer* uses Computing Services of the DTs Cloud Platform to develop a DT and publishes it into a DT Marketplace.
(4) *Computing service developer* designs Computing Services that implement models of real-world entities using in-house developed components, along with available applied software packages and frameworks.
(5) *Real-world entity* is a real-world process, system, or equipment fitted with sensors. These sensors gather and send the data to the DTs Cloud Platform for storage and analysis. Also, data can be received from derivative data sources, like SCADA, MES, etc., and typed manually.

As a direction of further research, we plan to design an architecture of cloud platform, that supports execution of Digital Twins and to provide resource management methods of the cloud system through "Container-as-a-Service" (CaaS) model.

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