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A flexible and adaptable workflow to develop and visualise industrial digital twins

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Abstract. A workflow for building a Digital Twin with a 3D interface for VR and desktop output was developed by focusing on the interaction with the virtual model, an easy deployment of the framework and a straightforward reusability. The case study was conceived for supercomputing datacenters, but its main strength lies in flexibility and adaptability.

Keywords: Digital Twin, Virtual Reality, 3DWeb, Industry 4.0.

1 Introduction

Replicating production entities, processes and systems as Digital Twins more than doubles the effectiveness attainable with design optimization, process control, life cycle management, predictive maintenance, risk analysis, and more [7, 8]. Anyway, the digitization of a "shadow" version [8] can be implemented through different solutions, from the simpler to the more complex and similar solutions can be adapted to radically different realities. Following the five-dimension digital twin model proposed in [2], a simple yet effective workflow was developed for the building of the digital twin of a physical entity. The workflow was tested first on an imaginary production chain, the Cube Cookies factory, then on the real test case, the CINECA supercomputing datacenter. Such workflow is focused on the interaction with the virtual model, the easy deployment of the framework and the straightforward reusability. The tool set is shaped in such a way that the system is deployed through a web-based application, thus without local software installation, and allowing easy-to-use interactions with the virtual environment by means of several input devices, such as the common keyboard and pointer, the extended reality devices as a cardboard using a smartphone or a virtual reality headset.

The dataset used for the supercomputing datacenter digital twin is taken by Examon [13] monitoring infrastructure, developed under the European project IoTwins [10]. IoTwins approach is based on a technological platform allowing a simple and low-cost access to big data analytics functionality, AI services and edge cloud infrastructure for the delivery of digital twins in manufacturing and facility management sectors. This workflow enriches the Examon infrastructure with an easy-to-use visualization component.

2 Immersive digital twin, from 3D Web to VR

2.1 Workflow

As shown in Fig. 1, the workflow starts with the creation of a virtual model using Blender [1], a 3D Computer Graphics toolkit, where CAD and BIM models can be easily imported and simplified. Notwithstanding, Blender allows to obtain a faithful replica of the physical entity thanks to its several tools for realistic computer-generated imagery.

Fig. 1. The developed framework and workflow for the building of a digital twin.

Besides, Blender allows exporting 3D models on a webpage by means of an add-on for Verge3D [3], a real-time rendering engine and Computer Graphics toolkit used to produce immersive 3D web-based experiences. This tool has multiple functions within the framework: it allows to obtain high modularity and standardization of the virtual model, for instance creating arrays of identical object components of the physical entity without the need to model each of them in Blender. In this way the virtual model can more easily co-evolve with the constant changes in the physical world. In addition to the geometrical modeling, it enables the behavioural modeling of virtual environments and of the digital twin itself, defining a set of actions and logics that the virtual world must perform to fulfill functions, respond to changes and interact with the user. Thus, in general, Verge3D enables the attachment of value-adding services to the digital twin, such as the real-time monitoring and diagnosis and the visualization of the digital twin connection data. Moreover, Verge3D, used in combination with Javascript library JQuery [4] and front-end web programming toolkit BootStrap [5], allows to quickly design and customize responsive website and interact with the digital twin by means of keyboard and pointer or thanks to the WebXR Device API with extended reality devices. Finally, Verge3D can run on several devices such as desktop, smartphone or tablet by means of a web browser application. The back-end of the web application for the digital twin is based on Django [6], a high-level Python Web framework. Django allows the management of the application of the website, the communication with databases of several types, supporting as many features as possible on all database backends. In this way, taking advantage of the AJAX call allowed by JQuery, the virtual model can query the databases hosting the digital twin connection data.

The framework can be easily reused and adapted to several physical entities, thanks to the workflow, which is based on the abstractions of the main processes, features and purposes of a digital twin and to the flexibility of the proposed tool set.

Fig. 2. Production units with annotations in the Cubic Cookies Factory. Navigation and interaction are performed with cardboard, through a smartphone.

2.2 The implementation

Two applications of the workflow described above are presented: the production chain of an imaginary Cube Cookies factory and the datacenter of CINECA supercomputing center.

The geometrical modeling of the Cube Cookies factory can be seen in Fig. 2 where the status information panel is built through Verge3D functions and can be updated in real-time from the application interface. The behavioural modeling function of Verge3D can also be seen in Fig. 2: if one of the production chain units stops functioning in the physical world, the corresponding conveyor belt in the 3D model, which would normally be animated, stops accordingly, thanks to the animation management features of Verge3D.

The geometrical modeling of Cineca datacenter can be seen in Fig. 3. As in the previous application, if a node of a rack of the supercomputer has an issue in the physical world, the corresponding rack in the 3D model would be highlighted with a red flickering outline, thanks to the post-processing features of Verge3D. Regarding user-interaction with the virtual environment, in Fig. 3 the rack door is opened by double-clicking on it, showing the red outline of a node. This allows a system administrator to identify the location, both in the virtual and physical world, of the node having an issue. The digital twin can be navigated in two modalities: on the website or using Virtual Reality. In the first case, the navigation happens through the keyboard and pointer, while in the second case, using the WebXR Device API the user can access the scene and use the controllers of the virtual reality headset or the cardboard pointer to move within the virtual environment or, as shown in Fig. 2, to point to a production unit and click to show its status information panel.

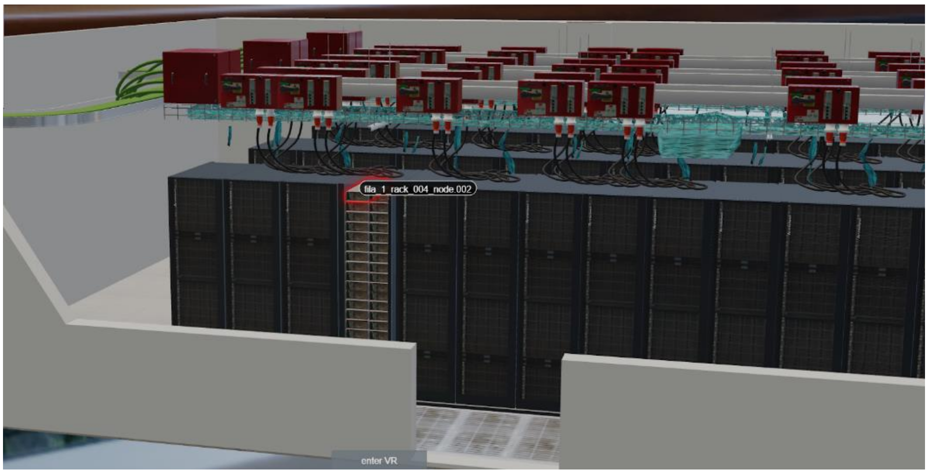

Fig. 3. User interaction and issue tracking in the data center digital twin.

3 Conclusions

We have tested the workflow on two digital twins: first on an imaginary production chain, the Cube Cookies factory, then on the real test case, the CINECA supercomputing datacenter. Such workflow is focused on the interaction with the virtual model, that we exemplified through the control panel in the Cube Cookie factory, the easy deployment of the framework and the straightforward reusability, that we demonstrated by easily adapting the workflow to both a shop floor factory and a supercomputing center.

The next step is to link online the digital twins with the Examon database to visualize in real time the datacenter behaviour. According to an Agile approach [12], use cases will be collected among the final users of the applications in order to address the requirements with adequate interactions. The digital twin, including the visualization system, will be replicated and deployed on the new CINECA datacenter that will host Leonardo preEXASCALE supercomputer, the next CINECA HPC cluster [11]. The Leonardo digital twin will be a complete monitoring system used by CINECA system administrator and technician to improve the ease of maintenance and reduce the intervention time in the case of failure.

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