Operations Research and Engineering Letters
Vol. 2, No. 1, 2023, pp. 21-27
ISSN: 2812-9318

Digital Twin Technology and Its Application in the Different Technical Disciplines With Reference to Construction

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Article Info

Article history:

Received Feb 3, 2023
Revised Feb 14, 2023
Accepted March 9, 2023

Keywords:

BIM,
Digital Twins,
Digital Twin Data-based,
Decisions.

ABSTRACT

The paper presents a complete analysis of digital twin technology from a detailed explanation of what digital twin technology is, through an explanation of which technical disciplines it can be used and what are the benefits of using digital twin technology with examples from projects.

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1. How was the Digital Twin Technology Created, and What Does It Represents Today?

The technology of making a digital twin model, in the format we know today, represents an existing or designed object or building and its identical copy in digital format, was created in 2002. NASA first used it in astronomy for producing and purchasing different components and systems from different suppliers. However, digital twin models have been primarily used to calculate the life cycle of components, systems, assemblies, and objects after installation, fabricatin, and construction. Essentially, digital twins were used to calculate the cost of maintenance or life cycle of various components, systems, assemblies, and objects by making various simulations of phenomena and processes on their digital format replicas that would occur on existing objects (Jovanović, 2020b; Lin et al., 2022).

By approaching the creation of a digital replica of an existing object, component, or system and simulating various “real world” influences on them in the digital world, we come in a much cheaper way to the data on all aspects and causes of life cycle costs of a particular object, component or system in a realistic environment and under the actual influences of various phenomena that interact with an object, component or system (Jovanović, 2020b; Jovanović, 2020c).

It is important to mention a few more things related to the digital twin. The digital twin is one of the hopes of the fourth industrial revolution, and the potential and savings this technology brings are becoming increasingly prominent. Digital twins can be classified in many ways depending on the point of view. The best way is to classify digital twins into digital twins of objects and buildings that are the subject of fabrication or construction and objects and buildings that have already been made or built. However, we need additional information about those objects (Jovanović, 2020a).

2. Digital Twins of Objects Being Fabricated or Constructed

With this type of digital twin, we typically mean objects that are subject to future fabrication or construction and that do not exist in the real world when making a digital twin model. Therefore, in this digital twin-generation workflow, we first mean creating a BIM model, which is almost always an object or part of it being designed. By object or part of a designed object means objects such as buildings or parts thereof, cars or parts thereof, production line or parts of a production line, dynamic objects, traffic simulation or pedestrian motion in various scenarios, and simulation of the destruction of a building (progressive collapse) (Jovanović, 2020a).

All the above objects or parts of objects that are subject to future fabrication or construction are characterized by the fact that from a BIM point of view, they can be considered fully static BIM models and cannot be attributed to the dynamic properties that underlie any simulation process (Jovanović, 2020a).

Figure 1. The BIM model enables the benefits of VR (Jovanović, 2020a)

With this, we conclude that the critical difference between the BIM model and the object's digital twin, which is the object of fabrication or construction, is the ability to simulate with different digital tools the influences from the realistic environment, that is, to apply different dynamic influences on the BIM model (Jovanović, 2020a).

3. Digital Twins of Objects That Are Made or Built

With this type of digital twin, we typically mean objects that are already made or built. Therefore, we initially face the question: "Why would you create a digital model or twin for anything already made or built? Apart from the additional cost, which cannot be considered any benefit, what economic benefit can one expect from such a model? "

A direct example from everyday life can be taken to understand the need to create a digital twin of existing objects.

We will use the analogy between rotary dial phones and modern "smartphones" and compare the levels of information the phones contain.

Previously, apart from the phone number, there was practically no information about the phone's owner. With the advent of smartphones, a wealth of information about the phone owner and the number assigned to the owner is available. Accessible international communication is possible via telephone numbers and specific applications. The information about himself that the smartphone user wants to share is accessible to everyone.

It is essential to mention that the first smartphone came out in mid-2007. Right now, it is impossible to imagine returning to the old handsets with the rotary dial since the capabilities between it and the smartphone are hard to compare. Both devices are phones but do not necessarily belong to the same category.

The question arises if it is necessary that, even though we have new and efficient digital tools to digitize existing objects, we need the facilities we have already built to be digitized. Why do we need it, and what will the digital twin of the made and built object serve us in the first place?

Take the existing building as an example and imagine the situation when walking through a building to ask the building owner what are the properties of a wall - what is its thickness, what material is it made of, what is the brand of the concrete wall, is it bearing wall, whether it has a finish and of which thickness. From this material, the finish is made, is the load-bearing capacity of the wall such that we can hang brackets for pipes of a certain weight, which is the fire resistance of the wall, whether we can make a hole in the wall to accommodate the damper and "pull-in" the cooling or heating duct when planning a wall painting, what is the wall area to calculate the cost of wall painting.

It would take a few days for the building owner to answer the above questions if we assumed that he did not have a digital twin model of the building. The building owner would have to go through a pile of paper to get the necessary information, contact the archive for some information and be unable to find some information.

However, suppose the building owner had a digital twin-building model. In that case, users get answers for some questions within minutes, and for slightly more complex questions, such as wall openings and wall-mounted pipe holders, they would get the answer within a few hours.

Through a straightforward example of an ordinary wall, we are seeing the potential of a digital twin of an existing facility, which, for example, can save significant financial resources by optimizing the cost of maintaining the facility, finding the best option for renovating, upgrading and adapting industrial facilities to a different purpose and finally when calculating the operating costs and life cycle of the facility (Jovanović, 2020a).

4. Digital Simulation Tools for Digital Twins Models

When discussing digital simulation tools for the digital twin, remember that we are entering the rainforest, and capturing all available tools is complicated. Therefore, we will list just a few essential digital simulation tools for digital twins and write a few sentences about each tool (Jovanović, 2020a).

CFD (Computational fluid dynamics) is a fluid dynamics calculation and is part of fluid mechanics, which uses numerical analysis and structured data to solve problems related to fluid and gaseous fluid behaviour. CFD analysis has an extensive application, including forces and moments on various digital models, pressure in tubes caused by liquid and gaseous substances contained in the tubes, explosion analysis, simulation of motion and flow of different types of particles, temperature action, simulation of weather, the behaviour of digital models in an air tunnel (Jovanović, 2020a; Jovanović, 2020d).

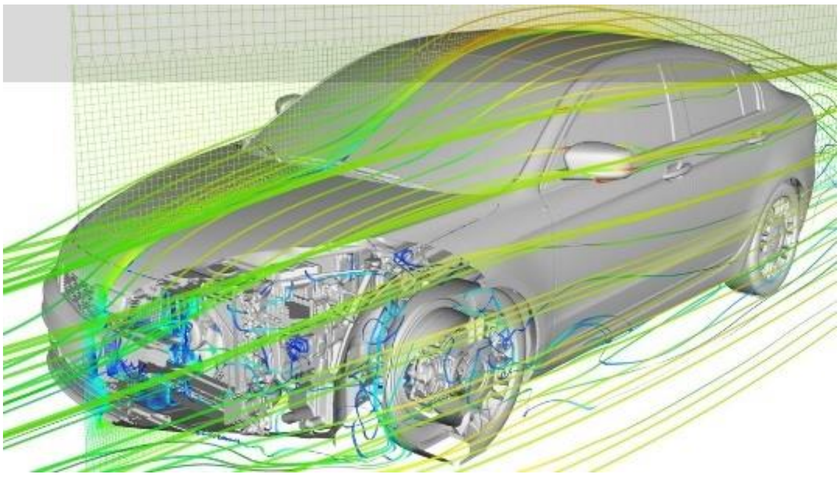

Figure 2. CFD (Computational fluid dynamics) (Jovanović, 2020a; Jovanović, 2020d)

Dynamo is a digital tool used for non-standard parametric modelling, generating additional and non-standard data for more efficient calculations within the BIM discipline model, for processing, manipulation, and easier visualization of generated data in the BIM model and orderly data exchange between different disciplines in a multidisciplinary BIM project process. Dynamo is a programming language and is based on the principle of visual programming. It makes it one of the favourite digital tools for automating the BIM project process because it integrates with the Revit platform and does not require additional procurement costs. Moreover, it is easy to learn and does not require much programming experience. A considerable advantage of including Dynamo as a digital tool for automating the BIM project process is that a once-written Dynamo script, which automates a particular logical part of the BIM project process, can be used on an unlimited number of projects. A well-designed Dynamo script applicable to multiple projects gives tremendous value and brings excellent savings to project participants (Jovanović, 2020a; Jovanović, 2020d).

Python is an object-oriented programming language most commonly used to generate, transfer, and process data in the BIM workflow. Python helps as effectively as the Revit plugin (PyRevit) or as part of

Dynamo scripts integrated into Dynamo "Node". What characterizes Python is that it is also a favourite tool in data science, system automation, and API development. Otherwise, the first book written to teach developers on using the Python programming language is called "Automate the Boring Stuff." This fact simplifies any further explanation of why Python serves the domain of BIM workflow automation, both for operations in the BIM discipline model and in a multidisciplinary BIM project environment (Jovanović, 2020a; Jovanović, 2020d).

Sensors - for made or built objects, different sensors are used to measure the values needed to optimize pre-existing elements within an existing object. For example, sensors can measure the number of people in a room. Then the data obtained can be compared with the data assumed by the architect during project design. If the number of people in each room is consistently higher than the assumed number, the building owner can optimize the machine's system of fresh air injection. Similar is possible with measuring the brightness of rooms. By comparing the data thus obtained, if an error is detected, the building owner can correct the deficiencies to give the building user adequate comfort (Jovanović, 2020a).

Machine learning is a digital tool that is defined as a sub-area of artificial intelligence. Machine learning is a process where a machine learns things based on the experience and imitation of human actions in certain repetitive circumstances (Puska et al., 2023). Machine learning is based on observing a person's actions when encountering a specific typical problem. After several repetitions, the program that "monitors the human" learns and adopts the algorithm of human behaviour and assumes the execution of the same operation that he learned "monitoring the human" (Jovanović, 2020a; Jovanović, 2020d).

Artificial intelligence still needs to make more complex decisions and look at the problems with data generated by different simulations (Divakar et al., 2022; Więckowski et al., 2023). However, we have yet to speak of the massive and default use of artificial intelligence as a digital tool to simulate the process in a digital twin (Jovanović, 2020a).

5. The Savings That Digital Twins Bring

By applying BIM workflow and digital tools used in various simulations on the digital twin model, and with proper BIM management of the complete BIM project process, there are between 5% and 15% more problems in the early stages of the project process that is, long before the contracting project and the construction of the facility itself, which brings significant savings to the investor financially (data given by investor "Lendlease") (Jovanović, 2020a).

The use of different sensors in buildings, which generate data through data processing platforms, helps to automate the equipment in the facility more quickly and efficiently, which improves the energy efficiency of the building and, at the same time, improves the comfort of the building occupants (Jovanović, 2020a).

By analyzing the data collected through sensors in already fabricated and constructed objects and incorporating such data in the design process of future objects, the investor makes significant savings in the speed of fabrication or construction of the object, the selection and installation of equipment, which, therefore, brings significant financial savings to the investor (Jovanović, 2020a).

By developing and permanently implementing a digital strategy, which involves developing digital twin models, incorporating different sensors into existing objects, and processing the data obtained from them, the investor receives "collective knowledge and experience" classified by object type, which in future projects of objects classified by type and purpose, brings significant financial savings at all stages of the project, then during the construction of the facility and in the life cycle of the facility itself (Jovanović, 2020a).

Given that it is difficult to expect a price drop in urban construction land and site fitting, the only segment where an investor in building construction can make savings is to optimize the implementation of the BIM workflow and to produce digital twins, in which the digital performance of the simulation tools will permanently improve the performance of the building in all stages of project design, during and after construction (Jovanović, 2020a).

6. Digital Twin Technology Application Examples

Vibration data were collected by using sensors on the bridge during regular traffic. According to the project documentation, following the norms from 1975, the bridge needed to be reconstructed. The client turned to Arup to check whether it was possible to postpone the reconstruction of the bridge for some time if the current norms were respected. Instead of the classical approach, where we would do static calculations according to existing norms, Arup suggested to the client that the sensors should be used to measure the vibrations on the existing bridge during regular traffic and thus assess the bridge's condition. Over the next four months, data on bridge vibrations during regular traffic were constantly collected, and this data was transferred to the "Cloud" via IoT (Internet of Things). After processing the data obtained from the sensors, the measured vibrations showed that, with minimal interventions where only one sensor showed higher vibrations than the prescribed norms, it is possible to postpone the reconstruction of the bridge for at least seven years. Let us consider that the bridge is located near the port, which has very intensive ship traffic. The client is provided with significant savings because it was not necessary to close the port during the two-month minimum work on the reconstruction of the bridge (Jovanović, 2020d; Jovanović, 2020e).

Figure 3. Vibration data collection by using sensors on the bridge during regular traffic (Jovanović, 2020d)

Using sensors in the already constructed building, Arup Architecture, at the request of the building tenant, requested temperature measurements in each room for a month to check the heating and cooling system after the construction of the business building. After the measurements and data transfer via the "Internet of Things" and then the data processing, the average temperature in each room was obtained during a previously defined time interval. The obtained data indicated that the average temperature in some rooms deviated from the expected values predicted by the project. In this case, the lower temperature than expected was an obstacle for the tenant of the business facility to achieve complete comfort. However, since the constructed building had its digital twin in the "Cloud" via IoT (Internet of Things) and Forge platform effortlessly, it was possible to adjust the heating and cooling system operation so that the tenant provides maximum comfort (Jovanović, 2020d; Jovanović, 2020e).

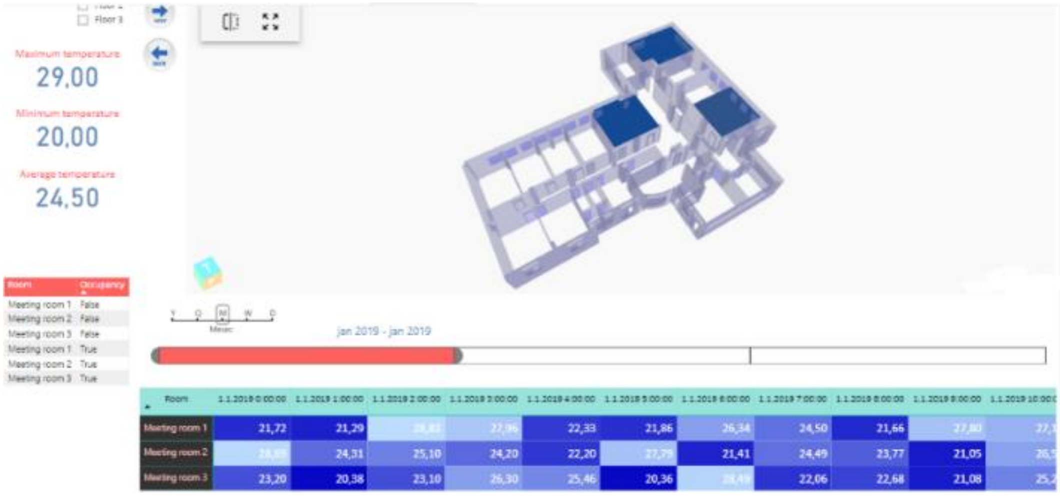

Figure 4. Temperature measurement (Jovanović, 2020d)

Courtesy of "Mat-real Estate", a company owned by the consortium "Matijevic", the company "TeamCAD DOO" made the first digital twin model of the existing construction facility "Sad Novi Bazaar" in Novi Sad. First, the BIM model of disciplines was developed, and then the BIM model was converted from the "Cloud" BIM 360 model to a web-based model of the digital twin on the "Autodesk Forge" platform. The reason why the BIM 360 Cloud model was converted to a web-based BIM model built on the Autodesk Forge platform is that all the power of digital twins remains trapped in the Revit model, which is often only available to a small group of users because to view and use such a model it is necessary to have licensed software, a sufficiently strong computer, prior technical knowledge related to the use of the software, access to the original file (Jovanović, 2020f).

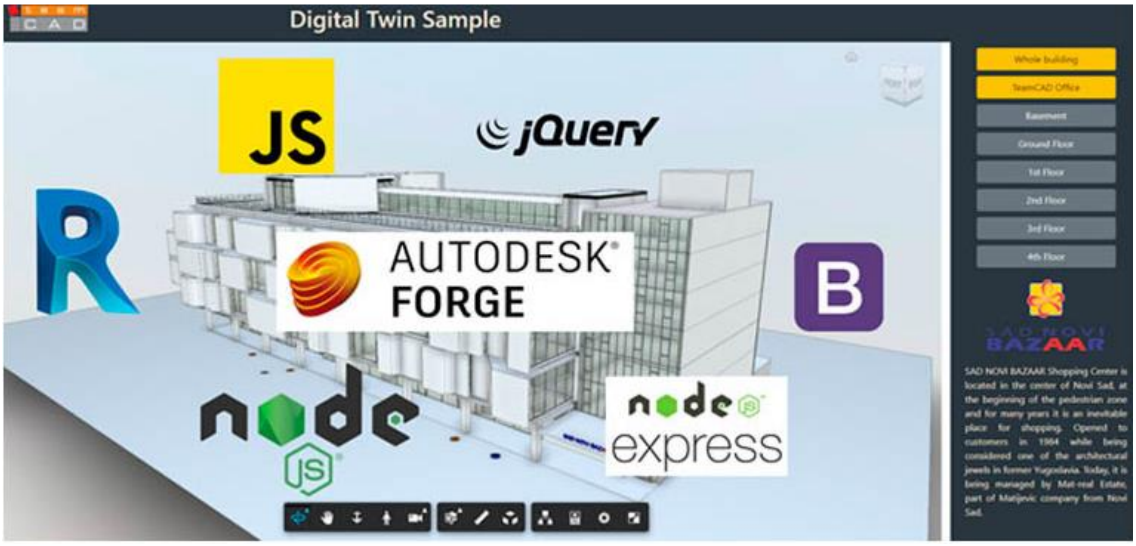

Figure 5. First digital twin model, "Sad Novi Bazaar" in Novi Sad

To make the digital twin with all the accompanying information available to many users, we have developed a web application that makes this possible.

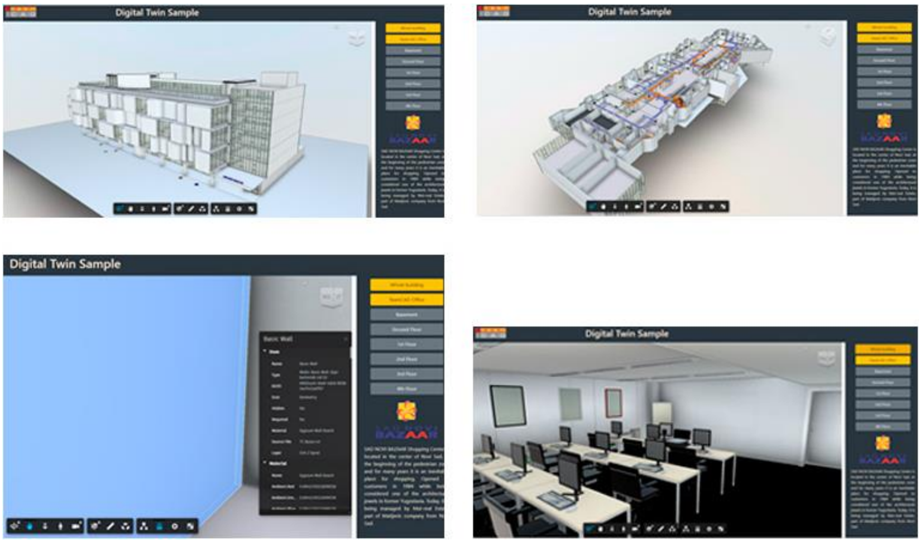

Figure 6. First digital twin model, "Sad Novi Bazaar" in Novi Sad

Web application relies on relatively new Autodesk Forge technology. The model is translated from Revit with all the information, while the rest of the application is programmed in JavaScript, relying on jQuery, Bootstrap, Node, and Node express (Guteša, 2020).

With the help of the offered web application, it is possible to access the digital twin from any modern internet browser. In the pictures shown, there is the first digital twin in Serbia. The shopping centre, "Sad Novi Bazaar", cooperated with the company Matijevic from Novi Sad (Guteša, 2020).

7. Conclusion

Digital twin technology is a relatively new technology, proving its value daily through optimization during the project development for buildings in construction and monitoring and optimizing the life cycle of the building and equipment installed in it.

The technology of digital twins strongly relies on BIM technology, and chronologically it can be said that BIM technology is the starting point for further elaboration of the project with digital twin technology. Apart from the project process, the technology of digital twins becomes irreplaceable in maintaining existing buildings. In the automotive industry, shipbuilding, aircraft industry, biomechanics, various digital simulations such as traffic simulation and simulation of evacuation behaviour during emergencies.

The most used simulation tools in digital twin technology are CFD analysis (Computational fluid dynamics), simulations, and procedures based on data generated by different sensors and processed by different data processing tools, most often using the programming language "Python".

Machine learning technology is widely used as an integral part of digital twin technology. After collecting and analyzing data, automated systems without human participation make decisions that achieve significant savings in the operation of equipment and entire systems to optimize the costs of their exploitation.

References

Divakar, R., Singh, B. ., Bajpai, A., & Kumar, A. (2022). Image pattern recognition by edge detection using discrete wavelet transforms. *Journal of Decision Analytics and Intelligent Computing*, *2*(1), 26–35. https://doi.org/10.31181/jdaic10029042022k

Guteša, V. (2020). Sad Novi Bazaar web interactive digital twin model. TeamCAD. https://www.teamcad.rs/index.php/srb/component/sppagebuilder/180-interaktivni-model-digitalnog-blizanca

Iyer, A. H. S. (2018). Digital Twin: Possibilities of the new Digital twin technology. Amazon Asia-Pacific Holdings Private Limited.

Jovanović, P. (2020a, February 5). What Are The Digital Twins? TeamCAD. https://www.teamcad.rs/index.php/en/news/298-what-are-the-digital-twins

Jovanović, P. (2020b, February 19). Digital Twins In The Construction Industry. TeamCAD. https://www.teamcad.rs/index.php/en/news/305-digital-twins-in-the-construction-industry

Jovanović, P. (2020c, March 4). Data Management In The Digital Twin Of The Building. TeamCAD. https://www.teamcad.rs/index.php/en/news/309-data-management-in-the-digital-twin-of-the-building

Jovanović, P. (2020d, June 3). Data Is The New Gold, Does The Same Apply To Data In Digital Twins? TeamCAD. https://www.teamcad.rs/index.php/en/news/392-data-is-the-new-gold-does-the-same-apply-to-data-in-digital-twins

Jovanović, P. (2020e, June 3). Sensors and IoT in The Digital Twin Technology. TeamCAD. https://www.teamcad.rs/index.php/en/news/399-sensors-and-iot-in-the-digital-twin-technology

Jovanović, P. (2020f, July 25). Analysis and visualization of data in Digital Twins technology – Cloud and Autodesk. TeamCAD. https://www.teamcad.rs/index.php/en/news/411-analysis-and-visualization-of-data-in-digital-twins-technology-cloud-and-autodesk-forge

Khaled, N., Pattel, B., & Siddiqui, A. (2020). Digital Twin Development and Deployment on the Cloud: Developing Cloud-Friendly Dynamic Models Using Simulink®/SimscapeTM and Amazon AWS. Academic Press.

Lin, K. Y. & Yao, Y. (2022). A Review of Digital Twin in Logistics: Applications and Future Works, Journal of Engineering Management and Systems Engineering, 1(1), 32-42. https://doi.org/10.56578/jemse010105

Puska, A., Štilić, A., & Stojanović, I. (2023). Approach for multi-criteria ranking of Balkan countries based on the index of economic freedom. *Journal of Decision Analytics and Intelligent Computing*, *3*(1), 1–14.

Więckowski, J., Kizielewicz, B., Shekhovtsov, A., & Sałabun, W. (2023). How Do the Criteria Affect Sustainable Supplier Evaluation? - A Case Study Using Multi-Criteria Decision Analysis Methods in a Fuzzy Environment, Journal of Engineering Management and Systems Engineering, 2(1), 37-52. https://doi.org/10.56578/jemse020102