Digital Twins as a common ground for interdisciplinary sustainability discussions

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1 DIGITAL TWINS FOR SUSTAINABILITY

Digital Twins (DT) are tools that are used to represent the real-time behaviour and performance of various types of physical systems, such as AI-based Autonomous Vehicles (AV), in a virtual environment. Vehicles, including AVs, contribute to X% of the global pollution. Therefore we can say that these systems are affecting a wide range of people: stakeholders with different backgrounds and goals. Even though sustainability might not be the primary focus of the design of AVs, it should always be a concern for all involved stakeholders [2]. DTs can connect different stakeholders together by providing a common ground for these interdisciplinary discussions.

Besides adapting to the physical changes in the system being analysed, DTs can also, in some way, predict the future behaviour of the system. This can inform about the expected behaviour of a system to the stakeholders, so that they can make decisions based on the most recent available data. Moreover, some stakeholders might be interested in auditing the potential issues that might occur during the operational processes and make the system function or respond in a specific way to avoid hazards or long-term effects on the environment. Finally, the real-world data processed by DTs could also be used for optimising the performance of the systems and making their behaviour auditable and traceable [?]. From the auditability point of view, data provided by digital twins could be used for "monitoring the energy consumption, analysing the productivity of the site and keeping track of carbon footprint of the vehicles," one of the experts we interviewed said. There is, therefore, a wide range of use cases for DTs connected to sustainability and, as a consequence, a large number of stakeholders with different responsibilities and goals.

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1.1 Ongoing work

In this ongoing study, interviews were conducted to gather the opinion of experts on how DTs can be used in different contexts and how they can contribute to the sustainability of the systems in focus. Future work includes follow up surveys with the identified stakeholders that could benefit from DTs to have informed discussions about sustainability. The study aims to understand each stakeholder's goals and responsibilities, and find out how data representation (e.g., interfaces) should differ for each of them.

The preliminary results of this work, point towards the following insights:

- The behaviour and performance of technological systems, including AVs, can be reflected in virtual environments with the help of simulation tools such as DTs.
- The collected data, once processed by DTs, could be used by different stakeholders for different use cases.

DTs can therefore be used to:

- create a common representation of real-world with different levels of abstraction
- present data in different formats to each stakeholder
- help connecting different stakeholders

Based on these results, we firmly believe that DTs can be the common ground for interdisciplinary sustainability discussions.

2 CONTEXT

Digital twins are widely used in industry for simulating the behaviour of real-world systems and they can adapt to different applications based on their context, therefore a wide range of stakeholders could be using the real-time data processed by digital twins. Real-time operators, third-party auditors, authorities are examples of those stakeholders.

DTs communicate gathered data with the stakeholders through interfaces. While different levels of abstraction of DTs could be used to collect and represent data, the stakeholders should get the information in an understandable way without the need to deal with the internal complexities of the DT. Therefore, choosing a suitable interface for data communication between DTs and stakeholders is critical. Furthermore, as we mentioned before, the data collected to update DTs is provided and interpreted by different stakeholders (e.g, third-party auditors, real-time operators, authorities, etc.) and for different purposes (e.g., managing a factory, policy-making, etc.).

Each of these stakeholders have different level and areas of expertise so the data should be provided at different levels of abstraction and complexity to them, therefore the way the data is presented to each of these stakeholders is important, Data could be presented in spreadsheets, plain text, 3D models, videos, pictures, etc. The digital twin's performance should be presented in an easy-to-understand format while being transparent about any limitations or uncertainties: dashboards, reports, and visualisations, as well as presentations, meetings, and reports to communicate the benefits of the digital twin and any challenges encountered during its implementation. Wu et al. mention virtual reality, mixed reality, and augmented reality as ways to present the collected data by digital twins to users. According to Cichon et al. several visualization tools including live images, 3D point clouds, network statistics, command line error log, 2D height map, etc could be utilized together to visualize data to a general support operator, nevertheless, in search and rescue systems AR and VR technologies are used to design the interfaces of remote operators [3]. Schroeder et al. suggest the communication of data through web services [6]. The interface directly affects a remote operator's performance as Mutzenich et al. mention high workload and latency of interfaces as the main issues of remote operating [5].

DTs could be used to represent data collected at different level of abstraction using different interfaces adapted to each stakeholder []. The type of an interface and its capability in terms of response time, user-friendliness, and adaptivity to users' needs are the main keys that result in an efficient communication of information between a system and a human [4]. Fong et al. discuss that, with the help of interfaces, humans can understand systems activities in the real world, monitor their performance, make decisions, and give orders when necessary [4]. While response time is the key feature of an interface used in some systems, understandability and precision of information are more essential for others. Therefore, different types of interfaces are used according to the functionalities and main purpose of the system.

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