Education, a corner stone for digital twin

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1. SUMMARY

Digital twin was first developed as a concept around the year 2002 at Michigan State University. The concept of creating a virtual environment identical to the physical environment is something that has developed over time. A digital twin can be seen as an instrument that combines and integrates static and dynamic data with each other. The dynamic data can come from active and involved participants, as such being citizen science. There are initiatives in the Netherlands where collected data by citizens becomes an important enrichment of the digital twin.

Within the digital twin, multiple users with multiple perspectives can acquire the data and insight they need for their specific cases. Where digital twins in the past were mainly used to serve one function or group, now a trend is visible of combining digital twins which offer multiple perspectives. Moreover, some nations are nowadays working towards a national digital twin.

Next to the evolving concept, the amount of dynamic and static data in digital twins is increasing. A future generation will grow up with already established digital twins. Engagement, data collection and their sharing are qualities and skills that are missing in education of today. It seems that citizen science is a perfect concept that can be introduced in the early education program. To take full advantage of the digital twin concept there is a need to adapt a school program where children can also learn about geo-tools, citizen participation and data collection. When covid accelerated hybrid and digital learning, new opportunities arose to make this a reality.

2. DIGITAL TWIN origins and characteristics

2.1 Digital Twins and its historical background

A digital twin consists of a physical entity, a virtual representation of that entity, and a bi-directional data connection that couples physical objects and processes to virtual counterparts, feeding data from the physical to the virtual world and vice versa (Glaessgen and Stargel, 2012). Thereby, digital twins are a virtual representation of the real world with the goal to model, understand, predict and optimize their corresponding real assets within the real world. The digital twin could link physical and virtual worlds in real time, which provides a more realistic and holistic measurement of unanticipated and unpredictable scenarios.

The concept of digital twin was first introduced by John Vickers of NASA in 2002 and was later further used and developed by Michael Grieves at the University of Michigan by looking at it from unique perspective in his whitepaper named "*The presence of virtual representation as Digital Twin*" (Grieves, 2022). Nowadays, the concept of digital twin is already in use in many application areas; however, challenges must be addressed (Rasheed et al, 2019). The revolutionary technology of digital twin has demonstrated successful applications in production science, applying the concept of digital twin on a larger scale such as a building- or city-scale comes with complexity due to the amount of data sources and data types that need to be integrated. This complexity is exploding as digital twin usage is being driven through the rise of Internet of Things (IoT) which describes the network of physical objects that are embedded with sensors, software, crowd sourced data and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. It is expected that the number of these devices and systems will increase enormously and so its data and complexity (Shafique *et al*, 2020).

In the future, we expect every available object in the physical world to be represented in a digital world, thus in its digital twin. It is estimated that in the next few years billions of things will be represented by digital twins, that digital twins will be utilized by half of the large industrial companies and billions of digitally connected sensors (Miskinis, 2019). Within these industries the digital twin proves to be a great tool for organizations to optimize their productivity and efficiency (Kritzinger et al 2018).

2.2 Characteristics of the digital twin

As seen in the last paragraph the concept of digital twin is evolving and its popularity growing. With the increase of popularity, we see a wide variety of types of digital twins on the market. Because the digital twin is present in many industries, such as designing, planning, maintenance, safety, decision making, and more recently education, it can also be associated with a wide range of characteristics within these digital twin types (Singh et al, 2021).

As the number of types of digital twin grows, digital twins can possess unique characteristics in which they differ from other types of digital twin, but regardless, all digital twins have a few characteristics in common:

- Multidisciplinary: The current digital twin concept revolves around many different perspectives on how it can be used. Different users can gain different insight by using the same digital twin.
- Reliability: A digital twin needs to be a near-identical copy of its physical counterpart in terms of form, contents, functionality with a very high degree of accuracy. Reliable models are considered the backbone of the digital twin (Reifsnider and Majumdar, 2013). This level of detail allows digital twin simulation and prediction tools to be more reliable when given with a set of various scenarios.
- Dynamic: Reality is dynamic, it changes with space and time. Therefore, a digital twin also needs to change as the physical system changes. This is achieved through the continuous connection and exchange between the physical and virtual worlds. Digital twin has been described as a 'living model in 3D' (Wired Brand Lab, 2020).

- Identifiable: Every physical asset needs to have its own digital twin. During different stages of the product lifecycle, the data and information related to it evolves and so does the model. It is recommended that the digital twin has a certain data ownership with each asset.
- Multiscale and multilevel: A digital twin, being the virtual copy of its physical twin, needs to integrate the properties of the physical twin at all levels and scales. Thus, the data in the digital twin is aligned on macroscopical properties of reality such as shape, size, etc, as well as on microscopic properties.

3. DIGITAL TWIN EXAMPLES

To gain a better understanding of the concept of digital twins, it is useful to investigate some examples of organizations which are developing one. This will help you gain insight and provide lessons learned.

3.1 Example 1: Rotterdam, the Digital Twincity

In Rotterdam, the Digital Twincity, the city recognizes digitization as being inextricably linked to all aspects of socio-physical life. Instead of being a useful instrument in the earlier days, digitization is becoming part of life in general. The municipality is researching the division of roles in this digital ecosystem in the Digital City Program. Including their own public role, by co-developing the 'Open Urban Platform' which connects the digital with the physical world.

The 'Open Urban Platform' uses the digital twin concept. Rotterdam is being visualized in three dimensions while connecting with real-time information about the functioning of the city. Together with internal and external organizations new applications and services are being developed within the Digital City Program for the "*Open Urban Platform"* to gain practical experience. For example, the 3D New Construction Plans app which views to-be built in 3D on a smartphone using Augmented Reality. It presents the construction project and its effect on the environment (van der Heijden, 2019). Such applications show the potential uses of a digital twin and the positive contribution to the environment. New insights can be gained by gathering all different data and information flows in one platform.

The created digital twin prototype currently runs in a testing environment, the Digital City Program is preparing for the next phases of its development. The municipality has launched a tender to build, launch, operate and further develop the "*Open Urban Platform"* with digital twin. The aim is to be operational mid-2023 (Cosic, 2022), further connecting the digital with the physical world.

3.2 Example 2: A Digital Twin of the Dutch Railways

The second example shows the development of a digital twin is a different context. Rail manager ProRail is working on a digital twin of the Dutch railways. The railway in the Netherlands is used by many different entities. These can be passenger and freight carriers, travelers, people crossing the railway and the manager of the railway itself. Currently, ProRail manages 398 train stations, 6.258 railroad switches, 7.183 kilometers of railway tracks and 28 different person- and/or freight carriers that use the railway infrastructure.

ProRail is responsible for asset management and traffic management of rail transport. Their vision focuses towards 5-dimensional location-based rail information while working data-driven. The 5 dimensions include 3-dimensional geographic information (x, y, z) combined with time and granularity. Granularity can be defined as the level of detail: how much information is recorded about an object. The level of detail determines the potential comprehensiveness of a digital twin. While one should always consider the needed comprehensiveness, to prevent people from being overwhelmed by the available information (Verhoeff, 2022).

ProRail aims to work in a data-driven manner, by creating a digital copy of the (future) outside world which is brought inside the office. This makes sure people in the field, like maintenance technicians and drivers, see the same thing as a train traffic controller inside the office. This digital copy of the outside world, the digital twin, is created with several different surveying techniques. ProRail uses sensors (IoT) in the tracks to measure passages, distortion, power consumption, etc. Also, special surveying trains, passenger trains with measuring equipment, drones, helicopters and satellites. To keep the digital copy up to date, surveying is carried-out regularly to provide near-realtime information (Voûte and Geldermans, 2022).

The survey provides a large amount of data, that is subsequently collected, cleaned, modeled and combined. On top of that, additional information from external organizations is added, like weather- or cadastral information, to complete the digital copy (Voûte and Geldermans, 2022). By bringing the outside world into the office ProRail aims to optimize business processes during all phases of their business operations. In the future, the digital twin should play an increasingly central role for the control and adjustment of business processes (Verhoeff, 2022).

4. CROWDSOURCING, EDUCATION AND DIGITAL TWIN

Technological development has fostered the emerging role of the citizen as a source of data. Due to easy access to the internet and the growing amount of mobile devices, it is now possible for citizens to easily acquire, share and use geographical information every moment. This activity has been named or described in a variety of ways, notably as crowdsourcing, volunteered geographic information (VGI), user generated spatial content, neogeography's and the pervasive media or citizens science. Shortly, all those terms refer to the data collected by citizens.

Integrating live data collected from sensors and citizens together with a 3D model of the city results in a valuable digital twin instrument that support municipalities in their daily decision making. A lot of municipalities in the Netherlands implement crowdsourcing and use already data collected by their inhabitants. One of the examples is the municipality of Zwolle that introduces the "natte voeten app" – an application for the citizens to monitor the impact of the heavy rain and flooding. By means of this application the citizens share the most actual situation about water level in their neighborhood adding photos linked to the location.

Based on the most actual data the municipality together with the help services can react faster and more accurately for this emergency. In fact, all citizens (young and old) can collect data and share it with their municipality.

4.1 Education system

Engagement, data collection and their sharing are qualities and skills that are missing in the contemporary education program nowadays. It seems that crowdsourcing (or other terms for exchange like voluntary geographic information (VGI) or citizens science) are perfect concepts that can be introduced in the early education programs. There are also many international initiatives that prove that children can be great data collectors and where their engagement and involvement can be easily activated and learned.

The first step towards increasing awareness in children about the high value of crowdsourced data and stimulate their involvement were made during various pilots by Kadaster, The Netherlands' Cadastre, Land Registry and Mapping Agency.

One of the pilots focused on checking the eagerness of school children to participate in updating the process of topographical maps and increasing geographical orientation. The curriculum included both theory and practice. The theory focused on explaining the term crowdsourcing, meaning and importance of the children's involvement in collecting data but also on explanation how their participation can help to keep the topographical maps up to date. For the practical part an online application with a feedback tool was provided. Pupils were asked to choose an area they know very well, find it on a digital map and provide feedback if they miss any object, they know it is in reality (e.g., buildings, roads, water).

Another pilot included a similar theoretical part about the importance of the data collections by the young citizens, this time supported by the impact of collected data on our safety. This time in the practical part children were asked to collect data for the emergency services. One of the important pieces of data that were missing was the obstacles on the internal roads. It was explained what the impact of this missing data is and how participation in collecting obstacles would decrease the time for the emergency services to reach the destination. Pupils were asked to inspect the neighborhood of their school and take a photo of the obstacle located on the internal roads. A special dedicated online application for collecting obstacles was provided. After the practical part all the results were highlighted on the dashboard in the classroom. The visualization of the number of obstacles collected by children in such a short time was impressive to them.

Those two pilots proved that children can be great data collectors and their engagement and involvement can easily be activated and stimulated. We observed that the good explanation about the importance of the data collection and its impact on others (use case with emergency services) make children more determined to help and collect the data. Another observation is that the curriculum should include a good balance between theory and practice. Theoretical part supported by films and visualizations were more appreciated by the children than a dry theory.

4.2 The future ambitions

The previous experience with promising results of the pilots was a trigger to start a new project focusing on involving children in the data collection. This time in cooperation with more partners like KNAG (The Royal Dutch Geographical Society), EduGIS (An association for geo-information and technology in education), Esri and Kadaster. The idea is to create teaching material with a uniform part explaining the value of participation and children's involvement in collecting data. The second, practical part, will be more variable depending on the actual and relevant topic. In the second part governmental organizations such as municipalities will get a chance to provide the use case. The collected data by children will be utilized by municipalities and will support the decision-making process (for example: placement of the playgrounds).

One of the future ambitions is to guarantee the topic of crowdsourcing and children's engagement a permanent place in the education curriculum. Crowdsourcing (or other modern words as replacement) can become, for example, an enrichment of geography classes. Investment in an aware and engaged society is one of the building blocks of creating complete and up to date Digital Twin to solve a variety and complexity problems of today.

5. CONCLUSION

The concept of digital twin has seen a lot of evolution in recent years. We have seen that through different industries and fields, different types of the concept of digital twin exist. The digital twin is therefore very much alive. Many different organizations are researching and developing its potential. The concept can be used for small- and large-scale issues, by private and public organizations. We have seen that building a digital twin is a joined task. The growing number of digital twin initiatives nowadays can be easily enriched by crowdsourcing, the data from the citizens (young and old). To increase awareness about the importance of engagement and the value of crowdsourced data, the educational program should be improved and extended. By investing in smart educational programs to enhance digital twin initiatives it will increase the chance to succeed in building a smart society.

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