Showcasing the First Steps Towards a Digital Twin for Campus Environments

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Abstract

This paper presents a path towards the implementation of a Digital Twin for campus environments. The main purpose of the Digital Twin is to accomplish an advanced analytical tool, which supports building owners, building operators and building users to reach an improved performance of the building. Digital Twins is new to the building and the real estate industry, hence research within this field is scarce. This paper contributes to the research by providing a methodology to implement a Digital Twin of an existing building stock of campus areas in Sweden. The main results obtained so far are presented. They indicate that the potential of a Digital Twin expands beyond the aspects of a navigational digital 3D model, including a state-of-the-art app that is developed from the Digital Twin platform.

Introduction

In 2020, the building and construction industry was responsible for 36 percent of total global energy consumption and 37 percent of energy-related CO_2 emissions (United Nations Environment Programme, 2021).

This calls for an urgent transition towards climate neutrality by 2050, as committed by the Paris Climate Agreement and the European Green Deal. Sweden has aimed for a bolder goal and through the framework of the Climate Act; the target is set for climate neutrality by 2045 (Ministry of the Environment, 2020).

The building industry is estimated to have the largest potential to reduce emissions (UNEP-SBCI, 2009). This would bring environmental, social and economic benefits as well as new business opportunities and jobs. Examples of societal effects are improved building standards and access to clean energy (UNEP-SBCI, 2009).

An increased demand for new buildings is challenging for building stakeholders, as energy consumption and energy-related CO_2 emissions must be drastically reduced. Building owners managing the existing building stock need to rethink their daily operations in order to transition their activities towards climate goals.

Digitalization within the real estate industry

The real estate industry is a slow adopter when it comes to new technologies and innovation (Baum, 2017). However, the willingness to shift towards a digitalized building stock has increased, as benefits and potentials have gained momentum. Digitalization within the real estate industry could imply the use of new technologies, sharing economy, tenant relationships and new services and business models (Vigren et al., 2022).

The Swedish trade organization, Fastighetsägarna, published a report in 2018, treating the digital readiness for the real estate industry. This was assessed through an interview study amongst Swedish real estate companies. One of the key results showed that 19 percent had implemented some kind of digital transformation. Therefore, one conclusion was that digital transformation is new to the real estate industry, as few market actors had discovered the potential. However, digitalization was perceived to be important for future development of the real estate industry (Fastighetsägarna, 2018).

Digitalization enables many new technologies and improved processes. Internet of Things, (IoT), enables the use of sensors and connected devices that allow real time monitoring of physical things and properties such as temperature, humidity and CO_2.

To understand how to reduce the climate impact from the built environment, it is necessary to comprehend and detect the main causes behind emissions. In order to do so, the use of data analytics and simulation will be crucial (Srivastava et al., 2019). Digital Twins enables both simulation and integration of available data and it is therefore a suitable tool in order to support improvements.

Aim and purpose

This paper describes the implementation process of a Digital Twin for campus environments.

The Digital Twin presented in this study combines sensor data with technical documentation and relevant third party information. It is a web-based tool providing an analytical instrument through its smartness and configuration of an analysis module that is designed according to user expectations. It also provides a navigational 3D geographical model, with a millimeter-precision of the model versus real world.

Alongside innovations and new technologies, the quantity of data collected in buildings increases rapidly. This data is often aggregated in data silos and limited to accredited users, making the sharing of data between multiple stakeholders complicated. One of the purposes of this Digital Twin is to establish a common data platform for tenants, building owners, real estate companies, and other key stakeholders.

The Digital Twin presented in this paper is as a first version developed as a tool for optimizing the use of campus indoor space. However, it is expected that other user aspects of this Digital Twin will appear as know-how develops alongside utilizing the tool.

The Digital Twin is built on a cloud-based Microsoft Azure platform, especially designed for Digital Twins. The Azure platform provides a flexible solution dedicated for buildings. The building owner designs the Digital Twin with object models, ontologies and populate it according to specific goals (Mateev, 2020).

First, the general concept and status of digitalization and innovation within the real estate industry is described. Second, the methodology for implementing the Digital Twin will be explained. Third, results will be presented and discussed, including future expectations.

Digital Twins in buildings

In order to transition from a resource demanding building industry to a climate neutral building industry, many unsolved challenges have to be tackled. Digital tools are important for this transition as they provide innovative means of utilizing resources more effectively. One type of digital tool that has emerged recently is the so-called Digital Twin. A Digital Twin could be described as a digital model of any physical object or process. The technology originate from NASA that developed a Digital Twin for the purpose of space flight simulation, but nowadays it is applied by many industries, for example the automotive industry, manufacturing industry and aerospace industry.

The concept of Digital Twin is new to research within the building industry. However, the growing number of publications within the field of Digital Twin technology reveals that attention has gained momentum during recent years (Sepasgozar, 2021).

A Digital Twin has many possible applications within the built environment. It can for example be used for material passport, allowing an overview of materials and their origin in order to minimize the amount of embodied greenhouse gas emissions (WorldGBC, 2019). This is often data that is managed in several different systems; hence, being able to handle this data in a Digital Twin would improve documentation and allow building owners to improve overview and trace climate impact from building materials.

There is no unified definition of a Digital Twin, leaving it open for various definitions. However, the literature seems to agree that a Digital Twin is a virtual or a "dynamic digital representation of a real system" (Boschert, 2018).

For the purpose of the Digital Twin described in this paper, it is defined as: "A digital model of a real system that coexists[1] and exchanges operational data and other useful information on a near real-time scale so that the operation of the real system can be influenced".

This definition takes a system perspective including the digital system, the physical system and their relation to one another.

Method – Implementation steps towards a Digital Twin

This section describes the process of the establishment of a Digital Twin for campus environments. Several building aspects and preconditions had to be considered. For instance, classifying rooms according to activity, deciding what type of sensors to install and where to install them. Any type of sensitive building related or personal information is also carefully considered. These considerations led to an approach consisting of four phases: Pre-Study, Sensor Installation, Model Generation with Reality Capture and Model Population.

Pre-Study

The pre-study phase is an interactive phase where stakeholders share and exchange general ideas about what a Digital Twin can bring in terms of an improved campus environment. The stakeholders in this case is the real estate company (building owner) and the campus real estate office (tenant). The pre-study phase consists of workshops with representatives from both the building owner and the tenant.

First, the purpose of the workshops is to communicate the vision and the goal for the project.

Second, buildings and rooms to collect data from and which physical properties to measure are identified. Relevant rooms were categorized depending on their size and function: auditoriums, lecture rooms and computer rooms, group rooms, lab rooms and offices (if applicable).

Default properties to measure were identified as follows: room occupancy, temperature, CO_2 and people counter. Noise measurement is included in some rooms.

Rooms that can be reserved by students and teachers for studies and lectures are connected to a room booking system. The comparison of data from the room booking system together with sensor data is expected to provide an improved assessment of the usage of indoor spaces as room occupancy data provides insight about how and when rooms are used. Results from this analysis are expected to provide important indicators of real use and demand for facilities and support decision making when planning for new buildings or renovations.

Sensors used to monitor occupancy are motion detectors; they provide binary result in the form of 0 (Presence: No) or 1 (Presence: Yes). However, the 0/1 constraint is a limitation of binary occupancy sensors, as they are not capable to account for the number of people present in a room.

[1] Thus; a digital model only cannot make up a Digital Twin.

Tracking indoor temperature can generate an indicator of the quality of indoor climate and thereby provide data for improvements or serve as a quality check. CO_2 concentration measurements provide an indication of the quality of indoor air, hence enabling data for fine-tuning of the ventilation systems.

People counters (Terabee, model M and L) gives the exact number of people located in a room and are therefore used as a complementary to the occupancy sensor. People counters are placed at the entrance to rooms that are used by more than 10 people, like for instance dining halls, auditoriums and lecture rooms (People Counting Systems (95% Accuracy) | People Traffic Counters (terabee.com)).

Noise measurements are not captured on a regular basis. Therefore, sensors that collect noise data are only installed at a few locations where noise level is perceived as relevant (for instance, libraries).

Common requirements for sensors are that they should require limited effort to be installed to reduce the installation cost. They must be GDPR-compliant, and the people counters cannot be equipped with any camera technology.

The sensor unit type is the ELSYS ERS Series (ERS – en (elsys.se)). These sensor units are capable to measure the relevant physical properties for the case of this Digital Twin (temperature, sound, occupancy and CO_2). This sensor type is wireless, it runs on two AA batteries, and is compatible with the LoRaWAN (Long Range Wide Area Networks) communication protocol.

Sensor Installation

The next step is the sensor installation phase. First, an inventory of the different types of buildings and rooms is established. This is important in order to select or deselect objects to be included for the sensor installation. Every building is carefully considered in terms of how and if it should be included in the sensor project. It is important to fully comply with current data protection regulation, as well as security for buildings connected to national security, server rooms and other buildings that could host any sensitive activities.

Some buildings are already equipped with smart ventilation systems providing CO_2 and temperature data that can be shared with the Digital Twin. These buildings are important to distinguish since no installation of any additional sensors is required in these locations.

The inventory also enables a synchronization of building information between the building owner and the tenant. This is to avoid any discrepancies between the two actors regarding intended use of rooms. As an example, a room could have been marked as a storage room by the building owner, while being used as a group room by the tenant. Consistently naming for rooms is thereby ensured. The inventory may also reveal minor renovations made by the tenant (for example, dividing a room with a wall), indoor changes that have not been registered by the building owner.

Second, physical properties to measure are decided. This is dependent on the type of room and its qualifications. Physical properties that are standard to measure are as follows:

- Auditoriums: Occupancy, temperature, CO_2, people counter.
- Lecture rooms and computer rooms: Occupancy, temperature, CO_2, people counter.
- Group rooms: Occupancy, temperature, people counter. (People counter in rooms dedicated for 10 people or more).
- Lab rooms: Occupancy, CO_2, people counter.
- Offices: Occupancy. (To be noted that this is only applicable where it is requested by the tenant to include office environment).

The building owner is responsible to perform a GDPR-investigation in order to make sure that all data generated and collected from the sensors are compatible with the General Data Protection Regulation, GDPR. This includes ensuring privacy, that individuals will not be identified through sensor data, clarifying ownership and access to data and ensuring that data is stored in compliance to policies of involved stakeholders.

Model generation with Reality Capture

The scanning process is divided into four main steps: Inventory (Preparation, Planning and Deployment), Generation, Integration and Publication. Both the building owner and the tenant must approve the scanning project before the scanning can start.

The scanning and generation of the point cloud requires adequate planning and logistics. The first step is to ensure that the inventory is completed. The inventory includes important information, such as technical information collected from facility management systems. The inventory is important for those who perform the scanning and for documentation.

Another important detail to prepare ahead of the scanning is to provide information to all affected parties. Students, employees and visitors must timely be alerted about the scanning of buildings and campus area.

A separate control of coordinates needs to be performed. This is done in order to obtain control points to ensure accuracy of coordinates and the point cloud. This work is generally done simultaneously with the scanning but could also be completed afterwards.

A time-schedule for the scanning is also prepared. The rooms to be scanned are blocked, as it is preferable to scan rooms without people. The scanning personnel receive the time-schedule, including inventory lists and other relevant information about the buildings and rooms. The facility management team are also involved to provide access to rooms and buildings. Scanning personnel is escorted by facility managers, especially in spaces where sensitive operations are being executed.

The second step is the generation of data. This step primarily involves data processing regarding security and quality aspects. This is done in order to comply with current data regulations, such as GDPR and to ensure data privacy protection. An algorithm identifies people and automatically blurs them, creating anonymized pictures. In addition, professionals in information security manually validate each picture. Text, photos and other personal or sensitive information need to be manually deleted, as the algorithm only recognizes people and cars. The picture-inventory is time consuming, but an important process in order to ensure GDPR compliance. For security and privacy reasons, some rooms are not eligible for camera scanning. In order to include rooms of a sensitive nature in the Digital Twin, an alternative solution was created. Rooms classified as sensitive, can be scanned only by using point clouds. This will generate a 3D model of the geometry, with black and white dots. Information classified as sensitive will therefore become challenging to distinguish. This is considered to be an acceptable solution for generating a digital model of geometries that contain sensitive information.

The generation of data include the integration of different data sources into the Digital Twin. This is information from various in-house and third party systems; building and facility management systems, technical and economic information, information about various system providers and sub-contractors or room booking data.

Outdoor environments are also included in the scanning phase. They are captured with a drone using orthophotography. This enables a more detailed view than satellite photos. The orthophotography allows a maximum deviation of 3 centimetres, which provides an acceptable quality to the Digital Twin outdoor view.

There are several approaches to design a Digital Twin of a building stock. A Digital Twin can be established from a 2D or a 3D model. For this case, Reality Capture was chosen to create an interactive 3D model. Reality Capture is the name for the software that gather precise data about an already existing environment (Almukhtar et al., 2021). Reality Capture uses a photogrammetry software developed for the purpose of creating 3D models of an existing indoor environment from camera photos or laser scans.

Laser scanning is a technology that enables Reality Capture; the laser scanning presented in this study is conducted by a hardware equipped with LiDAR (Light Detection and Ranging), a 360 camera (NavVis VLX) and SLAM technology (Simultaneous localization and mapping). The NavVis VLX is a backpack-based indoor mobile mapping system (Ready for anything | NavVis VLX 2nd generation). It has an improved accessibility and is more dynamic, compared to NavVis 6, which is a cart-based indoor mapping system (De Geyter et al., 2022). LiDAR is a laser technology that capture any given surface in three dimensions. The LiDAR sensor provides a precision of the scanning with a point density of 5mm. This allows a precise and accurate representation of a building stock. This fine-tuned laser scanning provides point clouds that frames a geometrical twin of the scanned indoor environment. Maximum allowed local deviation is 2 centimetre in order to gain a real-world experience and achieve an accurate measurement tool.

When using these tools there are two deviations to take into consideration; local deviation and global deviation. Local deviation refers to deviation between the real world and the scanned model. As an example, a door opening might deviate with 2 millimetres, when comparing the model versus reality. Global deviation refers to the deviation between the geolocated scanned model and a global coordinate system. This deviation is much higher than local deviation.

In addition to the backpack-based scanner, a stationary scanning machine, Leica BLK360, was used in confined spaces. This stationary scanner is a complement to access areas that are physically difficult to scan with the backpack. It provides a 3D point cloud for confined areas with the same or even better precision as the backpack system.

The point cloud is a 2D representation of an indoor defined plane (usually a floor). This is done through capture of real geometry by the means of coordinate points. The scanning hardware is complemented with a GNNS (Global Navigation Satellite System) hardware, that provides georeferencing in order to give every point its exact location. This hardware is equipped with SLAM that gives the sets each collected point into a local coordinate system. With the GNSS these points can be transformed to a global coordinate system. Adding x,y,z-coordinates to each point gives the environment its depth. The photos are also georeferenced and integrated with the point cloud. By doing so, a geometrical accuracy is achieved, providing the exact measurements and gives a depth and colour.

Data management is a challenge; due to the accuracy of 5 millimetres between every point, millions of data points are captured per campus area. The distance of 5 millimetres is a trade-off between accuracy of data sets and amount of data points. Processing this data is time consuming and computationally intensive. Therefore, data is captured in different data sets, to separately process limited amounts of point clouds.

The third step is the data integration where data are processed and integrated into the Digital Twin. The geo-referenced point cloud dressed with 360-images is integrated with other data sources, including the property managers real estate database and sensor data. The point cloud is processed in several steps while combining it into a 3D model and publishing all predefined data sets and images in the Digital Twin platform. Important basic properties such as navigation capability and building characteristics are integrated.

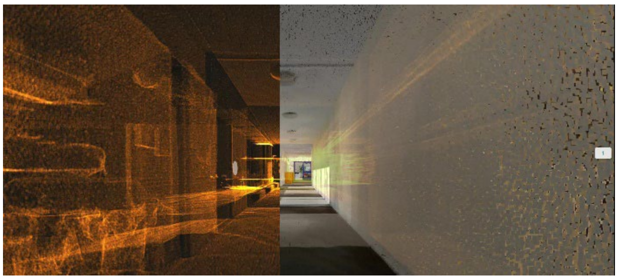

Figure 1: Example of a 3D point cloud

An IoT-platform was also established as an integration towards the Digital Twin platform. The IoT-platform is dedicated to collect and process sensor data (both in-house and third party data) before it reaches the Digital Twin.

Model population with data

When the geographical 3D model is completed within the Digital Twin environment, the fourth and last step is initiated. This step is referred to as model population. In computer science, the term populate refers to the action of filling empty tables with data. In this case, it means that data is processed and integrated into the Digital Twin platform. Objects are pinned and equipped with relevant information. Depending on requests from the tenant or building type, these objects could vary.

The population of the database with objects is a manual process; objects can be added or removed at any time. Technical documentation can be collected from facility management systems and imported into the Digital Twin. The purpose is to connect information to a specific building object to visualize or gather information in one place. Specific building objects could be fire extinguishers, sprinklers or elevators that is regularly subject to quality control. For this type of critical objects, the Digital Twin can produce a list including technical and maintenance information.

Digital Twin objects are classified according to the CoClass standard. CoClass is a Swedish digital classification system, developed by the building industry and based on the international ISO (ISO 12006-2 and ISO 81346-12) and IEC22 (IEC 81346-2) (Andersson, 2019). Classifying objects according to a standard is a prerequisite in order to enable a qualitative filter and search function. RealEstateCore (REC) is another ontology that is also administered in order to manage imports and exports of data from external IT-systems.

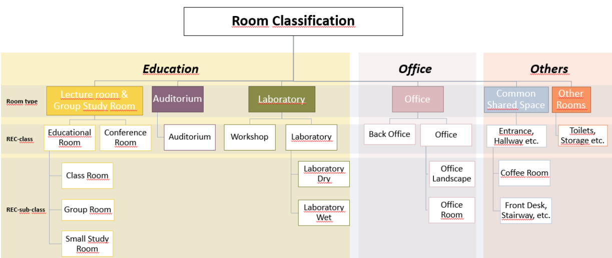

Figure 2: RealEstateCore (REC) Classification scheme

Geometrical information enabled by the point cloud is also included in the Digital Twin. This information may be used for renovation purposes or planning of suitable activities, since it enables correct measurements of walls and floors.

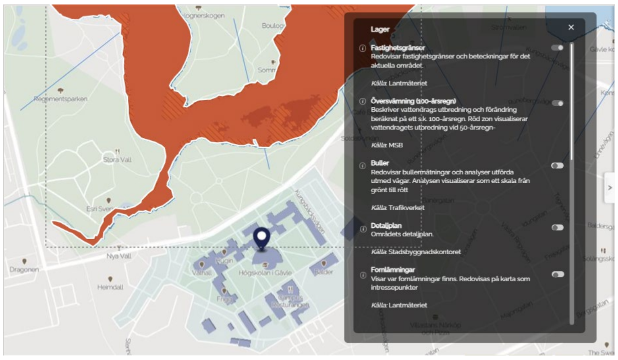

Figure 3: Digital Twin third party layer

The Digital Twin is also populated with data from third parties, presented in a layer especially dedicated for third party information. This layer is developed in order to present data from actors such as the Swedish mapping, cadastral and land registration authority (for example real property boundaries or ancient remains), The Swedish Transport Administration (for example ambient noise level), MSB-The Swedish Civil Contingencies Agency (for example precipitation statistics or 100-year rainfall) or City planning office (for example detailed development plans).

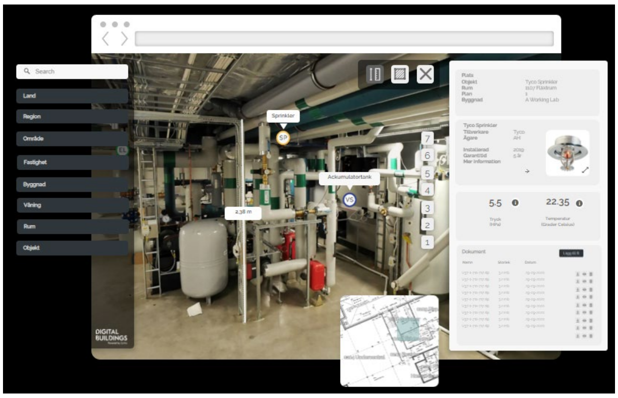

Figure 4: Mechanical room

Furthermore, the Digital Twin may be populated with data from building specific documents such as drawings of electricity, heating, ventilation and sanitation systems. Data from word documents, BIM objects and CAD drawings can also be imported.

Results

Five campus areas are currently involved in this Digital Twin project. One campus has implemented the Digital Twin, two campus areas are in the population phase and two campuses are currently in the pre-study phase. In total, 180 000 rooms have completed the pre-study phase and the inventory list. Also, about 20 000 sensors have been installed, providing about 100 000 raw data points every 10^{th} minutes. The learning curve for implementing the Digital Twin is still evolving as more insights are expected to be gathered throughout the process.

The Digital Twin presented in this study is still under development, hence the limited results. This section will present two main achievements so far, the analysis module and the campus app.

The Analysis Module

The first module developed in the Digital Twin environment is the analysis module. This module displays data from sensors installed around campus. Third party data may also be displayed, as an example data from room booking systems and authorities.

Data from room booking systems is imported in order to compare the data with occupancy sensor data. Combining this information will reveal the level of no-shows (where rooms have been booked but was not used). This will also reveal booking density per room. It is expected that behavioral patterns and trends regarding the use of bookable rooms will become visible.

This data is visualized in the Digital Twin, as well as presented in reports. The reports are developed to present which rooms are the most popular per given time unit, how many rooms were booked but unused (no-shows) and the distribution of the rooms that are more frequently used. The goal is to detect unused or less used areas and improve the level of usage.

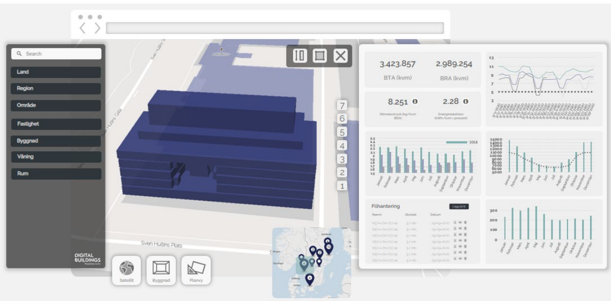

Figure 5: The analysis module

The Campus App

A mobile campus app is being developed as a complement to the Digital Twin and as a service to campus students, visitors and employees. The app delivers a user-centric approach and is unique in the sense that it is developed on the same 3D interface as the Digital Twin. Scanned indoor and outdoor campus environments are displayed in the app.

One of its main features is Wayfinding as navigation around large campus environments could be difficult for guest lecturers, newcomer students and staff members. Points of interest is another feature, where the users can pin locations of interest, like cafés or gyms.

This app collects sensor data such as occupancy or data from people counters. Data is consumed in near real-time and visualizes, for instance, when a dining hall is less busy or where a study room is available. This app is also connected to room booking systems, hence it will be able to suggest available rooms for studies and teaching.

Furthermore, the campus app will serve as a complement to in-person visits and marketing of campus areas. This is enabled by a feature allowing virtual round tours.

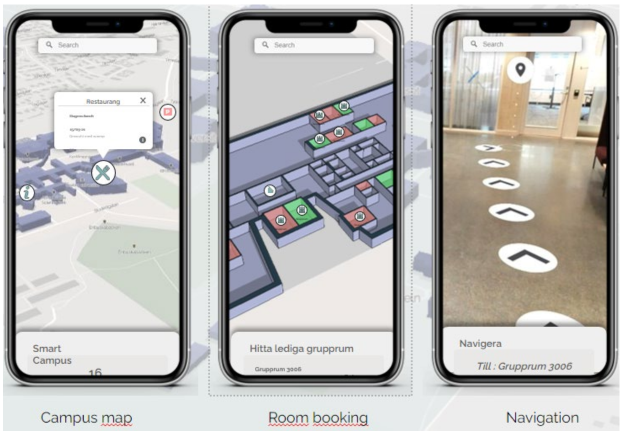

Figure 6: A sample of the mobile campus app interface

Discussion

Digital Twins are developed in order to simulate, predict and improve future conditions. It should be noted that the Digital Twin described in this paper is developed, as a first edition, in order to analyze how a building asset is used in near real-time and historically. The goal of implementing the Digital Twin is to understand how the building stock could be optimized, both in terms of short-term and long-term strategic aspects.

The Digital Twin is expected to detect unused or underutilized areas while combining sensor data for occupancy and people counters with data from room booking systems. With this new knowledge, existing buildings and rooms can be optimized by increasing the user rate in those locations. As an example, this could be feasible through rearranging room booking schedules or relocating certain activities. This could lead to a behavioral change of understanding how to fully optimize existing building assets and decrease the demand for construction new buildings.

The Digital Twin enables an innovative way of presenting and combining data. The analysis module enables analysis and visualization of building specific sensor data. The Digital Twin is unique in the sense that it offers a platform for combining building specific near real-time data with third party data in a user-friendly navigational 3D environment. For example, the Digital Twin could simulate a 100-year rainfall for a campus area, located in a risk zone of flooding. This could be used to locate buildings that are vulnerable and serve as an input for action plans.

The Digital Twin is developed as a flexible tool that may be reconfigured according to local demands and expectations from both the building owner and the tenant. Various local conditions as weather data or various urban planning aspects could also be included.

A considerable share of the building stock is older buildings and therefore building documentation consists

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of 2D drawings. As many of these old drawings was outdated or only accessible as hard copy, a scanning was required. Therefore, Reality Capture was used as a scanning process in order to establish a digital model of indoor environments. It should be noted that there are alternatives to create a Digital Twin model for a built environment, for example through using 3D BIM-models (Coupry et al., 2021). Scanning the campus environment was considered to be beneficial as it provides an exact copy of what these environments look like. As an example, a BIM model, which often represents an early phase of a construction project, does not include any changes, like renovations, brought to the building at a later stage.

The campus app as a service to the users on campus is enabled through the Microsoft Azure platform. By using the same interface as the Digital Twin, this app will provide an enhanced user experience when moving around campus. It is dependent on near real-time data that will display presence in study rooms. A future feature, also dependent on near real-time data, is visualization of presence in dining halls. When entering a post-pandemic phase, it is inevitable to consider how digital aids will become central for active decision making about where to locate.

According to the definition provided in this study, the Digital Twin provides near real-time data. The definition of “near” could be discussed. In this case, “near” implies every 10th minutes as this is the time interval for sensor signals to the IoT-platform and the Digital Twin. For the purpose of analyzing how and when rooms and buildings are used, a faster frequency of sending sensor data is not required. However, for future purposes that could imply time-crucial factors, such as taking immediate action on alerts, an improved signal would be relevant.

Conclusions and future work

In this study, a method to create a Digital Twin for visualizing, planning and optimizing campus environments has been presented. This study presents a Digital Twin as an interactive 3D model to visualize data and simulate reality in a navigational real-world environment. The focus is campus indoor and outdoor environments, however the procedure can in principle be adopted for residential buildings or other types of commercial buildings.

As an example, it can be used to visualize building data imported from building management systems, create automatic reports about indoor climate, level of usage and it can be used to navigate inside a building. It is expected that building owners as well as tenants and building users will benefit from the features provided by the Digital Twin.

It was noted that there are several possible approaches to create a Digital Twin, and the approach chosen for this study is based on the characteristics of an already built campus environment.

Future developments for the campus app could promote energy efficient behavior through various types of informative feedback. Students, visitors and employees contribute to the energy use on-campus and are generally not aware about their personal impact.

Adding a heat map to the analysis module is one of the future developments where spatiotemporal human patterns become traceable. This feature will provide real-time information about people movements around the campus area. Analyzing these movement patterns could provide information about outdoor areas that people avoid for some reason or identify dense areas where people gather. This knowledge could serve as information for projects aiming at re-designing and improving areas perceived as unsafe or optimizing building use at nighttime through gathering people in fewer buildings instead of keeping all buildings open.

Suggestions for future work and further development of Digital Twins for the built environment include: ensuring optimal indoor climate, improving energy efficiency and developing predictive analytic tools e.g. fault prevention. Another unsolved challenge is how to update an already scanned environment in a cost -and time efficient way.

The point cloud enables many opportunities. One possibility for outdoor environments could be to use Machine Learning (ML) and combine raw data from the point cloud in order to recognize certain materials, zones, recognize the condition of facades or automatically identify relevant items. ML could also be used indoors to detect energy-related trends and behaviors through utilizing the large amounts of available sensor data.

In the future it could be expected that buildings become to a higher extent connected to cloud services. It could therefore be assumed that the need for additional sensors for Digital Twins will be less common. Technical building systems, for instance HVAC-systems, will become more digitalized and automatically provide relevant and necessary data to the Digital Twin. Therefore, it could be expected that the future Digital Twin will become integrated with the physical building. It could also be expected that the future Digital Twin will be able to provide analyses in a cost- and time-efficient way. Furthermore, a future Digital Twin might be utilized to ensure building specific properties such as indoor climate and resource efficiency, as well as analyzing outdoor areas through integrating third party data with site specific data. It is evident that more research is needed to understand how various building related data should be combined and optimized within the Digital Twin interface in order to reach the full potential for a built environment.

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