Smart DCU Digital Twin: Towards Autism-Friendly Universities

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***Abstract*—Digital Twins are one of the emerging technologies which facilitate the creation of a digital replica of physical assets and infrastructure. The majority of initial use-cases of digital twins for smart cities and smart universities has focused on creation of the 3D representation of the infrastructure. However, with the maturity of technology, digital twins are nowadays used to build use-cases for smart applications which involve multiple sources of information including geographical information, IoT sensors and use-case specific knowledge bases. Smart DCU Digital Twin is one of the initiative towards achieving a smart university status for Dublin City University (DCU). Across the globe and in Ireland many universities including DCU are working on providing additional support to students with ASD (Autism Spectrum Disorder). The primary focus of these initiatives is on improving social interactions, and reducing academic and sensory barriers for the students. In this paper, we present our work on using digital twin technology to assist DCU in achieving its objective of becoming a fully inclusive and an Autism-Friendly university, with a particular focus on the reduction of sensory barriers for its students.**

***Index Terms*—urban digital twin, smart campus, IoT, digital models, immersive technology, autism friendly universities.**

I. Introduction

Universities worldwide are currently addressing the challenge of ensuring inclusivity and providing support to their students with special capabilities. A specific group of students who may require additional support are those with ASD (Autism Spectrum Disorder). Individuals with ASD [1], [2] have heightened or reduced sensory sensitivities. They may be affected by noise, temperature, light or the crowding of a particular scenario. A significant initiative, Autism-Friendly University, has been implemented in several academic institutions across Ireland, including Dublin City University (DCU). This initiative aims to support students with ASD by addressing three main barriers: social, academic and sensory [3]. Among the social barriers, some issues arise around feelings of loneliness in the university campus and the inability to cope effectively with stress and anxiety. These feelings can manifest as feelings of isolation or general depression, as well as avoiding social interaction. In terms of academic barriers, some of the challenges faced include difficulty coping with the sensory conditions of busy lecture halls, leading to avoidance of lectures; difficulty accessing support and information from university services; and challenges navigating the academic environment. Finally, in terms of sensory barriers, some of the challenges faced include heightened sensory awareness of noise, crowded environments, temperature and lighting. It manifests itself in difficulty navigating social events, restaurants and lecture rooms, especially at peak times, due to crowding, noise and limited space. Bright colors on walls and fluorescent lighting can increase students' sense of discomfort. While some potential solutions have been proposed to address these three issues, the challenge of sensory barriers is particularly significant given the dynamic nature of the campus and the difficulty of tracking and predicting its condition.

The goal of monitoring the state of a particular space in real time is addressed by an emerging technology called Digital Twin. Urban Digital Twin is being developed in the context of smart cities to improve the quality of life for citizens by monitoring the dynamics of spaces in real-time, including both indoor and outdoor environments. In the context of current research, the technology has been applied to the university environment, leading to the development of a smart campus or smart university as a Digital Twin application scenario. Despite the potential challenges in real-world implementation, Digital Twin technology can be used to facilitate addressing certain issues, and providing a foundation for supporting students with ASD is one of the use cases.

Sensing the physical environment plays a crucial role in the application of smart universities, which is supported by an increasing amount of research in this area, with a particular focus on educational facilities [4], [5].

A conventional university campus guide might provide students with information about the various spaces and facilities, focusing solely on usability or purpose. For students with ASD, such information may not be sufficient to gain a good understanding of such spaces, leading to overwhelming discomfort or even sensory overload. Traditional university systems do not take into account potential unpredictable stimuli that may be distressing for students with ASD. For example, areas with sudden loud noises, flashing lights, overhead projectors or unexpected physical interactions can be sources of anxiety for these students. Traditional universities don't provide advance warnings or alternatives to avoid the zones mentioned above. This sensory data, often considered irrelevant to the wider population, can be critical for people with ASD. This calls for specialized tools such as autism-friendly monitoring of university spaces based on Digital Twins. This technology enables the monitoring of the condition of the university environment by integrating spatial information such as 3D reality data models, building information modelling (BIM), and real-time dynamic information such as room occupancy, temperature, humidity, light and noise levels.

Digital Twin technology already has a place, but its application has yet to be explored entirely. This study investigates the application of Urban Digital Twin technology on the university campus to support the development of an Autism-Friendly university. Being inclusive is a step forward in creating a better society where everyone has the same opportunities regardless of their neurotype, thus the inclusivity of universities is an important issue to consider. This paper is structured into VI sections - section 2 covers the literature review related to students with ASD in university environments and applications of Digital Twins in smart-university scenarios. Section 3 highlights the case of the Smart DCU Digital Twin campus and its Autism-Friendly University initiative. Section 4 discusses the methods and materials used for the investigation, and section 5 covers the results and findings of the study. As this study is part of an ongoing project, the limitations and future research directions are discussed in the conclusion section.

II. Related Work

A. *Students with ASD and university environment*

The prevalence of ASDs has increased steadily over the past few decades [6]–[8]. In the context of the university environment, it is important to avoid stigmatizing any students with disabilities and to create an inclusive environment that encourages people to apply for higher education and supports them during their studies to successfully complete their programme. As the number of university students with ASD increases, it is crucial that these students have access to appropriate support [9]. Given the combined social and academic demands placed on them, support for students with ASD must include both social aspects and the creation of an inclusive physical environment, with the aim of reducing factors that can cause stress and anxiety. It emphasises a 'mindshift' in services for students with ASD, moving the focus from 'physical and mental health' to prioritising 'wellbeing' and quality of life. In this context, the Autistic SPACE framework was developed to improve access for autistic individuals to public facilities. This framework aims for equitable service design by prioritizing sensory considerations, predictability, acceptance, communication, and empathy [10].

Moreover, nearly 20 universities across Europe have already adopted the Autism&Uni online toolkit, which provides students with information and strategies to overcome the challenges they typically face when transitioning to university [11]. Autism&Uni was funded by the European Union under the Lifelong Learning Programme between 2013 and 2016. Since 2016, Leeds Beckett University has continued the project, involving new universities that are willing to adopt the toolkit for their students [12]. In the meantime, many universities are using self-developed programmes for students with ASD. For example, Marshall University (USA) has developed the College Program for Students, which identifies goals and strategies based on each student's individual needs. This programme helps students learn skills, receive emotional support and navigate the academic environment [13]. Adelphi University (USA) has developed the Bridges to Adelphi programme, which provides individualised academic, social and vocational support services for neurodiverse students [14]. Eastern Michigan University (USA) offers the College Supports Program, which aims to increase the admission, retention and full enrolment of students with ASD through an individualised, fee-based support programme. In addition to academic achievement, the programme focuses on the development of social-emotional, communication, and daily living skills necessary for adult independence [15].

Lately, a 2024 study by DCU explored the university experiences of students with ASD [16]. The findings revealed a diverse range of experiences, highlighting the need for inclusive approaches that recognise autistic neurology and differences in order to promote a sense of belonging and acceptance in university settings. Additional challenges included experiencing the learning environment as hostile due to sensory issues on campus. This highlights the importance of developing inclusive physical spaces alongside inclusive social environments. Environmental factors have a significant impact on the emotional well-being of students with ASD, making it essential to monitor and optimise physical spaces. In this context, Digital Twin technology is emerging as a valuable tool for assessing and improving physical environments to better support the needs of students with ASD.

B. Digital Twin in the context of the Smart Universities

Considering the significant interest in Digital Twin across a range of industries, many universities around the world are implementing the technology. Kaunas University of Technology (Lithuania) applies Digital Twin technology at the campus level to estimate operational carbon emissions, monitor indoor climate, and improve the energy performance of university buildings. The system integrates a geometrical three-dimensional model with sensor data, supporting the monitoring of the university environment. APIs broadcast more than 2,000 parameters in real time from physically installed sensors across the university campus, with further data processing and analysis [17], [18]. Another example is Western Sydney University (Australia) which explores the use of Digital Twin technology within the concept of a "living lab" for a university library building. This approach supports building facility management by proactively optimizing indoor conditions and simultaneously considering occupancy levels based on motion detection [19]. The University of Galway (Ireland) has developed a three-dimensional virtual model of the campus, created using a combination of surveys, RGB images, and photogrammetry. This model supports master planning procedures, provides a visualization of the university environment, and aids in planning security and traffic [20]. A similar approach is adopted by the University of Birmingham (United Kingdom) which uses 360-degree views and photographs of various points of interest, including campus buildings. Additionally, the university has outlined a strategy for further developing its smart campus, which includes an integrated BIM strategy, occupancy monitoring, and a navigation and wayfinding platform [21]. Hubei University of Technology (China) also employs a smart campus system based on a Digital Twin. The architecture of the system combines a static virtual model with a dynamic data model. It is primarily used for visualizing a virtual campus environment, offering features such as campus guided tours, augmented reality experiences, and virtual simulation teaching [22]. The present overview indicates that Digital Twin technology has the potential to facilitate the development of smart university applications. It can be used to improve a wide range of services and support that universities can offer to their students, which is a crucial aspect of improving inclusivity.

III. Smart DCU Digital Twin And Autism-Friendly University Initiative

DCU being one of the leading universities in Ireland has many opportunities for innovation and technological solutions. Smart DCU is the collaborative effort between the Dublin City Council (DCC), Insight, Enable and DCU Alpha, launched in July, 2019 to develop and test leading technological solutions in a microcosmic representation of a city environment with core infrastructure such as housing, restaurants, workplaces, shopping and recreational facilities. Under Smart DCU umbrella, Smart DCU Digital Twin was proposed, this project is one of the pioneering partnership launched in 2021 between Insight SFI Research Centre for Data Analytics at DCU, DCC, Bentley Systems, and Kaunas University of Technology. The focus is to investigate the potential of digital twin technology and immersive solutions for real-time visualization of intricate environmental and contextual data and assess its impact on key stakeholders and the public.

DCU serves as a small-scale representation of a city and with this groundbreaking collaboration DCU is evolving this microcosm of a city into a Smart City ecosystem. By working together, these institutions aim to leverage their collective capabilities and expertise to develop Ireland's first higher education digital campus. This is an ongoing project and intends to incorporate AI-driven analysis of real-time data from IoT sensors, including temperature, humidity, light and noise levels, campus occupancy, waste management, energy and water usage, air quality and any crucial data that can be used to improve DCU services and infrastructure management.

DCU believes that any student should have equal opportunities regardless of their condition. So, committed to that, in 2016 it started an initiative to create the first autism-friendly university in Ireland [23], initiative that 18 months later became true when DCU was designated as the first autism-friendly university in the world by the autism advocacy charity AsIAm [24]. Lately, as part of this initiative a guide was created, where besides social and academic barriers, a great focus is on the sensory barrier [3]. This guide emphasise the importance role that technology plays in having an Autism-Friendly campus, in that sense Smart DCU was linked to this initiative. In short, Smart DCU Digital Twin is one of the enabling technologies for Smart DCU with the objective of creating a live digital replica of the Dublin City University campus aiming to foster better quality of life, services and management on campus and most importantly in providing better services as the world's first autism-friendly university.

IV. Methods and Materials

The presented methodology is primarily based on the Bentley ecosystem as shown in previous work [4]. However, as for Autism-Friendly Universities indoor spaces are also of interest, in this work indoor scanning was also integrated to the methodology as shown in Fig. 1. Images are acquired using drone surveys and handheld photos, which are then processed and transformed to a digital 3D model using Bentley's iTwin Capture Modeler (CC) [1] and Polycam [2]. These models are further integrated using OCP (OpenCities Planner) [3] and Unreal Engine. OCP is used for publishing the DCU Digital Twin along with some sensors data. Data

[1]https://www.bentley.com/software/itwin-capture-modeler/

[2]https://poly.cam/

[3]https://www.bentley.com/software/opencities-planner/

from IoT sensors are streamed via 3rd party dashboards/APIs or streamed and stored on the Bentley's 4DA (4D Analytics) platform [4]. Unreal Engine and Twinmotion are used as well to create more immersive virtual spaces and experience.

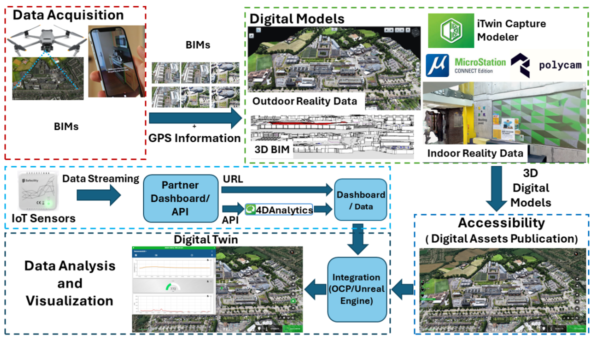


Fig. 1. Digital Twin methodology integrating indoors and outdoors.

A. Data acquisition

As presented in [4], outdoors spaces were mapped using a drone DJI Mavic 2 pro. The dataset was created by executing drone surveys on each of the four campuses of DCU. However, this work focuses in the campus called Glasnevin since it is the main and largest of the four of them. The drone survey was executed at an altitude of 100 m over the ground and its image database is constituted by 1,699 files.

To collect images of indoor spaces, flying a drone is a difficult task, since our drone is big to be maneuver in such areas. Instead, handheld photos were taken using an iPhone 14 Pro Max. This phone, besides normal cameras, is equipped with a LiDAR camera that can be leveraged.

Scanning using the iPhone 14 Pro Max and Polycam works for small spaces with low ceilings. However, for large spaces with high ceiling and complex material such as glass or shiny surfaces this approach will struggle. It will be also difficult to model a whole building using this technique. To tackle this problem, BIMs provided by DCU were used.

B. Digital Models

Digital 3D models of outdoors were created using iTwin Capture Modeler, it processes our database of drone images to create 3D digital models of the DCU campuses. The models created using this software can be reality data, point clouds and can be exported in different formats according to the final use. For this work reality data meshes were used.

Indoor 3D digital models were created using Polycam. This application can process handheld photos from normal and LiDAR cameras such as the ones equipped on the iPhone 14 Pro Max and produce 3D digital models. This software also creates models in different formats according to the user needs, in this work reality data meshes were used.

[4]https://www.bentley.com/software/assetwise-4d-analytics/

3D BIMs are only available for the new buildings such as the new Polaris building that is still under construction. Old building only have 2D BIMs. For the case of spaces with missing 3D BIMs, Polycam was used to create the 3D digital models and then they were retouched using Twinmotion to give a more realistic look by adding materials and objects.

C. Accessibility

To address the issues of accessibility with students two options were explored:

OpenCities Planner. A cloud-based platform developed by Bentley Systems that allows for the management and organization of digital assets. It also provides an intuitive space to create projects based on those assets. It is a quick and easy option to showcase any digital asset by only creating and sharing a URL link. Regarding IoT sensor data, this tool provides a function called link embedding that allows for inserting a public link to external web pages or dashboards.

Unreal Engine. It can manage multiple digital asset formats such as 3D reality data meshes and BIMs, along with streaming of IoT sensor data. Unreal Engine also allows to create a variety of visualizations based on IoT sensor data. A very useful capability of this tool is that our digital twin project can be hosted on a server and then be accessed by the students by sharing with them a URL. Besides gaming controllers, virtual reality headset are supported to explore virtual environments which provides a better immersive experience.

D. IoT Sensors

The 3D digital models created are only digital assets resembling a campus, a building, or a room, but they cannot be called digital twins unless there is an exchange of data with the physical world. For that reason, the following sensors were used to enable real-time monitoring. From WIA, forty sensors report room occupancy, temperature, humidity, noise and illumination level. From HiDatai, two sensors monitor the number of people, noise and illumination level in two rooms using computer vision and deep learning techniques.

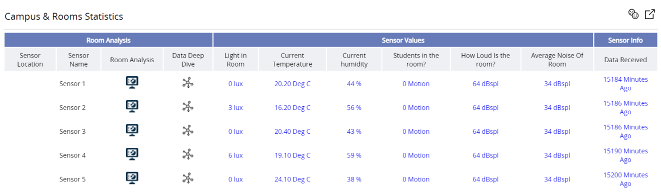
E. Data Analysis and Visualization

Not complex data analysis was performed. However, data visualization plays a big role when trying to communicate to the students the dynamic state of rooms or areas of interest. WIA and HiData, have their own APIs and dashboards to stream and visualize their data. However, for the purpose of creating more suitable visualizations Bentley's 4DA is used to stream, integrate, analyse and store data from the devices in a single platform. 4DA allows the creation of custom visualization of data along with easy integration into digital models. 4DA has some limitation to create some basic visualizations such as bar or line graphs. One of the objectives of this work is to create more immersive visualizations of IoT data, for that reason Unreal Engine is used.

V. Results and Discussion

A. *Efficient Data Management and Analysis*

To manage the data from sensors 4D Analitycs was used to collect the data from WIA. 4DA retrieve and store the data on the cloud, then its API is used to access the data from our Digital Twin. 4DA allows to stream, store and fuse data from different sensors creating a common environment where all the sensors can be accessed in real time. For now the 40 WIA sensors were successfully integrated into 4DA, where all different type of signals are streamed and stored as presented in Figure. 2 Regarding HiDatai sensors, their provided dasboardd and API was used. For now, we only have two edge computing sensors installed, therefore using their basic dashboard and API is enough, Figure 3.


Campus & Rooms Statistics

Room Analysis				Sensor Values						Sensor Info
Sensor Location	Sensor Name	Room Analysis	Data Deep Dive	Light in Room	Current Temperature	Current humidity	Students in the room?	How Loud Is the room?	Average Noise Of Room	Data Received
	Sensor 1			0 lux	20.20 Deg C	44 %	0 Motion	64 dBspl	34 dBspl	15184 Minutes Ago
	Sensor 2			3 lux	16.20 Deg C	56 %	0 Motion	64 dBspl	34 dBspl	15186 Minutes Ago
	Sensor 3			0 lux	20.40 Deg C	43 %	0 Motion	64 dBspl	34 dBspl	15186 Minutes Ago
	Sensor 4			6 lux	19.10 Deg C	59 %	0 Motion	64 dBspl	34 dBspl	15190 Minutes Ago
	Sensor 5			0 lux	24.10 Deg C	38 %	0 Motion	64 dBspl	34 dBspl	15200 Minutes Ago

Fig. 2. WIA: 40 sensors reporting light, temperature, humidity, room occupancy and noise level.

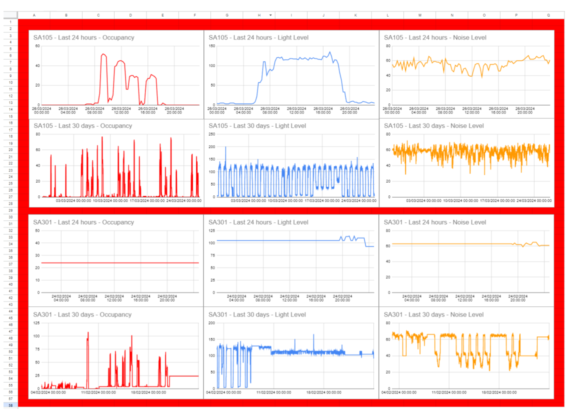


Fig. 3. HiDatai: Two computer vision-based sensor reporting room occupancy, light and noise level.

B. *Exploration of Dublin City University*

DCU has four campuses, for now, this work focuses on the Glasnevin campus because is the biggest and more information is available. Glasnevin campus has some facilities such as a theatre, a sport center, a pub, a shop, a pharmacy, and a Students' Union building. There are also some special places for students with SDA such as a Wellness Centre, a Quiet Space and Sensory Pods around the campus. Currently, there is also a building in construction called Polaris that for now it is not possible to visit. The objective of Smart DCU Digital is to create digital assets of all the buildings and rooms in DCU, to start we focused on some rooms of interest such as the Inter Faith Centre, the Wellness Centre, some classrooms, the U Building and the main garden of the Glasnevin campus (the Mall). The Inter Faith Centre and the Wellness Centre were selected because they are spaces where students go to relax and spend time away from the crowd. Classrooms, the U building, and the Mall were selected because is where students spend more of their time when in campus.

1) Outdoor exploration: Using drone photography and iTwin Capture Modeler a 3D reality data model of the Glasnevin campus was created, as presented in Fig. 4. To create a rapid showcase of our digital twin OCP (OpenCities Planner) was used. OCP allows for a quick integration of 3D digital models on the cloud that can be accessed by end users by only sharing a URL. OCP, allows as well for an integration of IoT sensor data on top of our 3D digital model by creating POIs (points of interest), then this POIs will contain a link to a dashboard that can be seen by only clicking the POIs.

Fig. 4. Dublin City University Glasnevin campus.

The dashboard can be as simple as the one shown in figure 5 where the visualization were done on an Google Sheet document retrieving real time sensor data from HiDatai or something more elaborated as shown in figure 6 where WIA sensors are being stored on 4DA. 4DA also allows the creation of a dashboard for a specific sensors. The image 6, shows a dashboard created for the sensor 16 placed on the U Building, room SA105. The user can select the time frame of the data to be shown- months, years, days. When a range of days are selected, the user can select any point in the graph of the dashboard and see the sensor reading at a specific hour. By doing this, users can get a general idea of the normal dynamics of the rooms and if needed see the current readings of such room, then based on that, they can decide if that room is suitable for them or not. This can be used as well for the university to monitor the dynamics of rooms an make changes accordingly to create a better atmosphere.

Due to different factors such as the altitude at what the database of images was taken, illumination, and other environmental elements, certain level of detail can be obtained in the generated 3D mesh model. So, to reach a more immersive atmosphere, objects detail, and integrate different type of 3D digital assets, Unreal Engine is used. Unreal Engine allows to integrate different digital assets such as realistic trees,

Fig. 5. Opencities planner integrating real time data sensor from HiDatai. Room SA105: room occupancy, light and noise level.

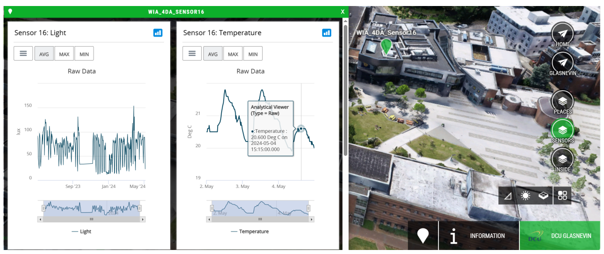


Fig. 6. Opencities planner integrating real time data sensor from WIA.

furniture, and specific object of interest that were modeled individually to reach a better quality. Figure 7 shows some examples of the objects of interest in DCU, i.e: E-bikes, E-scotters, Big Belly Bins, benches. It can be seen that the quality of the trees and vegetation can be improved by replacing them with object from the Unreal Engine library.

Fig. 7. Reality data mesh model vs Unreal Engine retouch.

2) Indoor exploration: To create 3D reality meshes of indoor spaces, handheld photos were used and processed with Polycam. Figure 8, shows the main area of the interfaith centre where students can go to play board games and grab a tea/coffee from the kitchen. The results provide a realistic digital model that allows students to have an idea of what to expect of that area before vising it. One interesting room in the Interfaith Centre is the Quiet Room where students can relax and be away from any disturbance. However, the temperature or lightning condition of the room can be dynamic or the room can be occupied by other students. For that reason, this room has installed one of the WIA sensors. As shown in the figure 9, by exploring our digital twin students can see the static features of the room such as coloring, textures and objects, as well as the real time dynamic features of the room such as occupancy, temperature, humidity, light, and noisy levels. Based on this, students can decide if this room is suitable for them.

Fig. 8. Interfaith Centre: 3D mesh model.

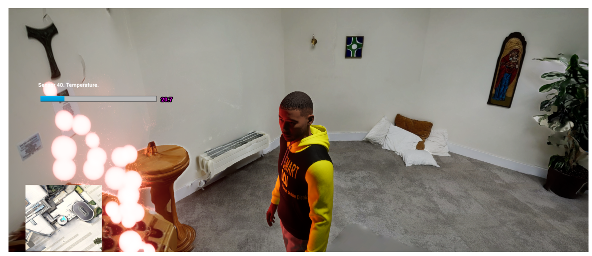


Fig. 9. Quiet Room: Unreal Engine integrating 3D mesh and sensor data.

Modeling 3D reality data meshes using handheld photos and Polycam can be challenging, this software depends on photogrammetry which is affected by several factors such as the quality of the images, illumination, and textures. Besides that, it was noted that spaces with several object in it are more challenging to map since it is difficult to get photos of the object from different perspectives. Looking at this challenge, we have two option, empty the room and do the mapping or create a model of the room and then add objects to it. The first option was not possible for security reason, therefore we decided to create a digital 3D plain model of the room and then add object to it. The wellness room has some object of interest such as some flowers made with Lego toys by people with disabilities, as well as some games and books of interest. This object were modeled individually and then added to the model. All the integration of the models was done in Twinmotion and then exported to Unreal Engine where real time IoT sensor data was integrated on top of the 3D digital models. Figure 10 presents the integration of the 3D models to create the wellness room, and as this is a room of interest to be monitored, a WIA sensor was placed in each room. The overlay of IoT real time sensor data is presented in figure 11.

Fig. 10. Wellness Room: 3D modeling using Twinmotion.

Fig. 11. Wellness Room: 3D modeling using Twinmotion and IoT real time sensor data integration using Unreal Engine.

For some of the new buildings in DCU, there is available proper 3D BIMs, these models contains all the geometries, and objects that forms a building such as room, doors, windows, halls, and certain materials and colors. Currently, in the Glasnevin campus there is a building in construction and its BIM was provided. This model was leveraged to create a realistic 3D digital model that allows users to explore the building before is finished. As seen in the figure 12, more complex objects such as stairs, big halls and high ceiling areas can be modeled using proper BIMs.

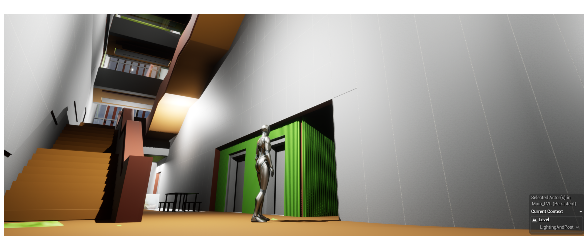


Fig. 12. Polaris building using BIMs.

3) Indoor path finding guide: Buildings can be very tricky and rooms can be difficult to find. One common issue faced by students, staff and visitor that creates stress is the finding of class rooms, bathrooms, labs and any indoor space. Thinking in that challenge and thanks to the availability of the 3D BIM of the Polaris building a solution was developed. BIMs, when they are imported into Unreal Engine a general map of collision for walls, stairs, floors and ceiling is created. Unreal Engine knows the areas that can be accessed. This property is leveraged in this research work where a blueprint was developed to allow the user to select a room of interest from a list, then an avatar will guide the user to the selected room. People learn in different ways, some are visual and learn by watching, other people learn by doing. Having that in mind two ways of interacting with this guide were developed. The first option is where the user selects a room of interest, then the avatar will start walking towards the room and show the path to follow on a camera screen that is linked to the avatar. The second option is where the user select a room of interest, then the avatar guide will start walking towards the selected room, different to the first case, this time the user has the option to follow the avatar guide with a given avatar that represents the user in the digital twin of the Polaris building, similar to the actions of playing a game. The top picture in the figure 13 shows the guide avatar, then the middle picture presents the guide avatar in action showing the path to follow to the select room as a video camera screen. Finally, the picture at the bottom shows the avatar in action being followed by the avatar representing the user.

Fig. 13. Indoor path finding. Top: avatar guide. Middle: avatar guide in action showing the path on a video screen. Bottom: avatar guide being followed by avatar representing the user.

VI. Conclusion

This work describes the use of Urban Digital Twin technology to help Dublin City University to have autism-friendly campuses, and similar to what [3] mentions, this work can be used as well to support all autistic users of campus- staff, visitors and general community. This final section presents the conclusions drawn of this study and future work that align with the challenges faced in this research work.

In the development of this research work it was seen that 3D modeling has advanced enormously in the recent years and meanwhile there is not a solution that solves all the challenges there are several techniques that complement each other. As seen in the described methodology, we used different techniques and tools according to the environment to be modeled going from drone imagery, handheld photos, to BIMs. Different type of software was also used such as iTwin Capture Modeler, Polycam, and Twinmotion.

Regarding IoT sensors, we conclude that different options are available in the market. However in order for these sensor to be used in a specific environment we had to ask for permission to place those sensors. This was possible thanks to the support of Dublin City University by providing the permission and the communication infrastructure to be able of consume and use this data for this research work purpose.

Another challenge faced in this work was to find tools with the capacity to integrate 3D modeling and IoT real time sensor data. The two options explored in this work, OpenCities Planner and Unreal Engine, provide great capability for this integration that is worthwhile exploring further.

Utilizing the mentioned methodology our future work will be focused on increasing the number of spaces or areas of interest in Dublin City University to be mapped and monitored with IoT sensors. In this work we are only scratching the surface of data visualization and analysis then the next step will be to improve the visualization of real time IoT sensor data and perform AI data-driven tasks such as prediction of the dynamic state of spaces or anomaly detection such as detecting too crowded or noisy rooms.

Acknowledgment

This publication has emanated from research conducted with the financial support of Science Foundation Ireland [12/RC/2289_P2] at Insight the SFI Research Centre for Data Analytics at Dublin City University; The authors also thank Bentley Systems and Dublin City Council for the support and funding; The Care&Connect team, Annabella Stover and Fiona Earley, for their guidance.

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