Virtual Environmental Imaging Technology Enhances Maintenance of Biomedical Assets

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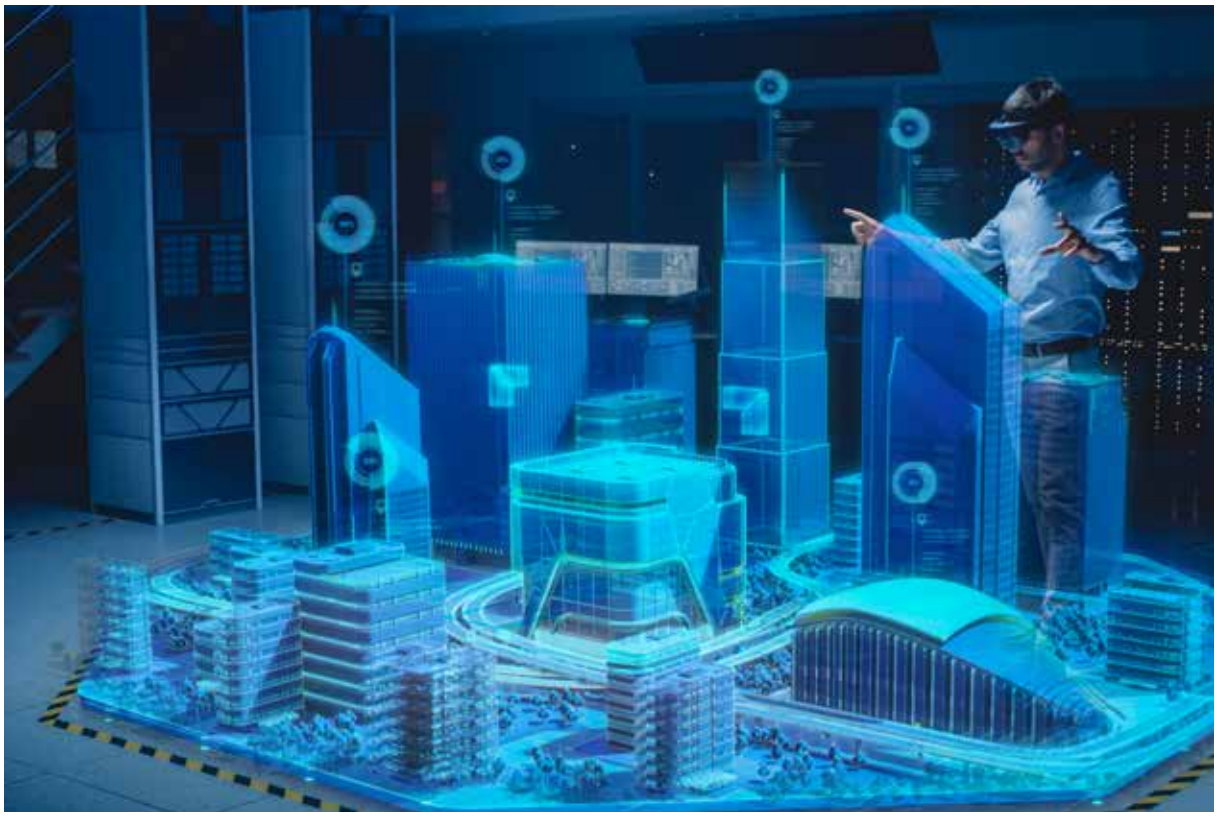
Government hospitals provide a wide range services and house many facilities including biomedical equipment to ensure 24-hour healthcare services. The hospital's facility managers need to leverage current resources to ensure minimum interruption to all critical functions which heavily rely on various type of biomedical equipment (BE). There are opportunities to integrate the use of emerging technologies such as 3D virtual environment imaging in facility management services of hospitals. The visualisation capability provided by such technology could greatly improve BE maintenance management process such as BE inventory upkeep, BE operation and routine maintenance processes, BE replacement and upgrades and BE safety and health. It also helps in the disaster management process as seen in increased mobility of BE across the Ministry of Health (MOH) facilities during the recent COVID 19 pandemic. The feasibility and acceptability of such technology in BE management should be further explored to optimise disaster response as well as out-of-hospital management of BE. MOH have taken a keen interest in such technology and is moving forward to test and implement such tools in this era of distance learning and distance managing.

Increasing Trend of 360 Image Virtual Environment

Panoramic virtual reality can create highly realistic and detailed representations of the real environment while giving users a sense of immersion (*Pereira et al., 2017*). 360 cameras have huge potential across domains such as retail, construction, tourism and even cultural heritage due to its versatility enabling users to capture the world with an omni-directional view with just one shot (*Fangi et al., 2018*). Advances in computer technology led to 3D modelling and visualisation that is now commonly being used in



360 images can create digital twin of real-life space

urban planning as well as property development related activities. Real estate and developers have turned to immersive technologies to give buyers a more interactive online experience to access and view the built property or unbuilt property development. The virtual tour of built property is made up of 360 images of the location created by 360 compatible camera or imaging devices.

There are many cloud-based software or programmes that can process the 360 images to create a digital twin of the real-life space and creating a 3D virtual tour. The 3D virtual tour allows viewers to have a 360-degree perspective of the property at any point in the house and even take accurate measurement form the virtual model. Property agents could also add information in the virtual tour through digital labelling that provides narration, images, videos and even document that can be downloaded. Research by *Afrooz et al., (2018)* have shown that 3D digital modelling has been well received as a toolkit for urban planning process making the development application process (DA) in Sydney Australia faster and efficient. The DA process involves documentation checking such as forms, 2D site plans, consultant reports but lack 3D data visualisation that makes it difficult for most people to envision the approved building presented originally in 2D. Therefore, there has been keen interest in using 3D models not only in the DA process but also for community engagement, streetscape, and urban design as well as interior design exploration.

Teicholz, (2012) has explained in his book about technologies like 3D modelling and simulation tools for facility management processes that can save time and money as well as assists facility managers to identify optimal or near optimal solutions. Use of such business intelligence (BI) facilitates managers in better budgeting and optimal allocation of resources in repair, renewal, and modernisation of ageing facilities. Building visualisation using 3D digital model as well as building information modelling (BIM) shows great promise and is increasingly endorsed by facility managers as they need more efficient ways to

collect and access information for maintenance and operation of most facilities (*P. Teicholz, 2013*). However, research have shown that 360 Image-based Immersive Virtual Environment (IVE) could potentially improve human experiences and performance compared to traditional IVEs although they provide less interactivity (*Amezquita Radillo, 2022)*

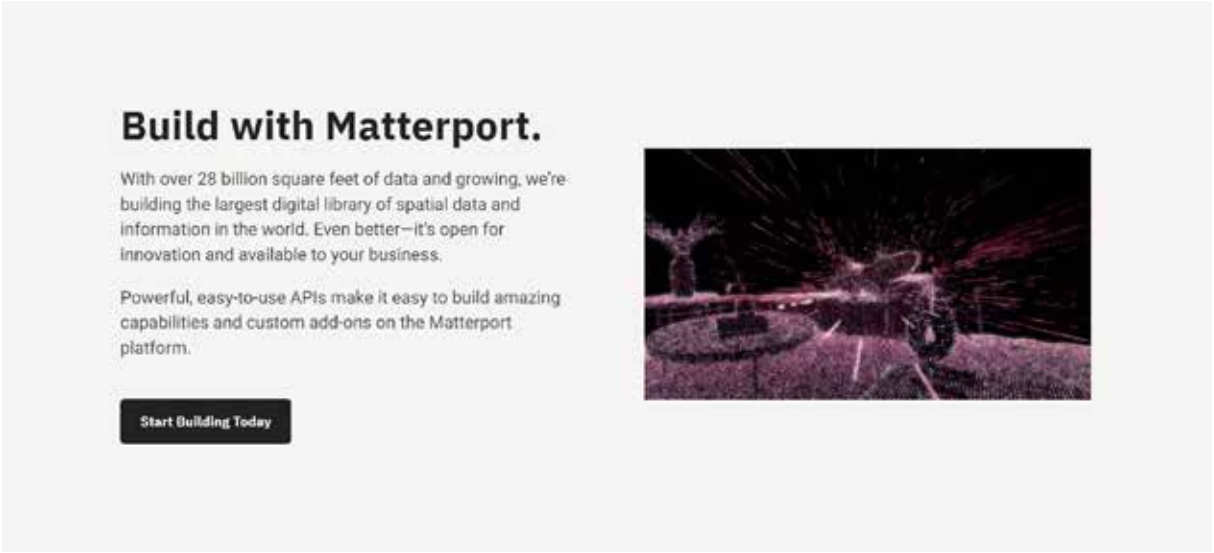
Visualisation is an important tool in the process of education and training, not only in the classroom but also for open learning via the web (*Haque et al., 2005).* The same tool has become an important part of facility management that requires training for new or visiting employees so that they can quickly navigate the facility and get work done. The 3D walkthrough training tool also contributes to increase in situational awareness for staff and even serve as a guidance to better respond in case of emergency or disasters incidents. The same approach was used by University of Western Australia that has developed a 360 virtual laboratory tour to help its first-year students to familiarise and prepare for an upcoming laboratory class (*Clemons et al., 2019*).

Lovelace, (2019) has shown in his survey that the Department of Transportation Minnesota have been using image equipment such as 360 camera and light detection and ranging (LiDAR) to create and utilise 3D modelling to document its existing facilities, communicate inventory and inspection data. Scanning technology such as Ni drones, LiDARs, cameras and lasers as well as processing software can be used to digitally document building sites, exteriors and building interiors to effectively manage these important assets. 360 cameras have also been used with drones to carry out bridge inspection making the inspection process more cost effective and safe (*Humpe, 2020*). Similar methods have also been made in conservation, assessment and management of historic buildings. 3D reality based on 360 scenes is being used as a versatile tool for smart documentation of historic building and allowing remote access for users, technicians and authorities to evaluate conservation and safety measures for the historic buildings (*De Fino et al., 2022).* Very recently, *Chow et al., (2021)* have introduced a work method for automated defect inspection on concrete structure which utilise 360 camera and LiDAR. The image and LiDAR data allow mapping and integration of the structure defects into a BIM model to better manage facility. Digital transformation has been driving more effective practices in variety of domains including asset management. A broad spectrum of advanced technology and solutions are available which include drones, 3D interface, 360 images laser scanning, web services and mobile apps that should be assessed at system level due to its multi-dimensional benefits. (*Kortelainen et al., 2020*)

Challenges in Biomedical Asset Management in MOH Facilities

The outbreak of COVID-19 has increased demand for hospitals' specific treatment facilities. During the pandemic, the surge of COVID 19 patients led to over stressing of certain BE assets as well as increased demand for ventilators. The current asset information system, ASIS, which contains the inventory of BE across hospitals has limitations especially in out-of-hospital interventions and managing of critical BE asset at hospital level. The module in ASIS computerised information system currently contains records such as asset register, user area and user location for every MOH hospital. The system only records and stores text-based data without any form of visualisation format therefore making it difficult for the information system user who is unfamiliar with BE to verify and visualise the BE itself including its location. Location and asset ID are required following any breakdown complaint by both equipment users and maintenance personnel, which could be time and cost-consuming even before any corrective action can be taken. Therefore, visualisation technology such as the 360 image-based virtual environment application allow more efficient facility management processes resulting in quick respond time and timely corrective action. Usage of such tool not only allows effective BE maintenance and uptime, but also improve optimisation of emergency planning and response in critical events such as the COVID 19 pandemic.

Timely location verification of BE asset is also essential to avoid theft and misplacement, especially in the ward department, where sometimes BE assets are found in unintended



locations or not found at all. This situation could be life threatening if critical BE is not found and sent to where it is needed urgently. The current practice of physical verifications seems to be lacking due to complacency and issues related to human factors.

Sarawak General Hospital Pilot Study- Feasibility and Acceptability

A feasibility study was carried out in Pathology Department, Sarawak General Hospital to demonstrate the feasibility of 360 image based virtual environment model and acceptability by stakeholders and relevant key persons. A 360-image based 3D digital model as shown in Figure 1 was created using Matterport technology representing indoor layout and include other useful content such as digital asset tagging, and other information deemed critical for BE asset managers.

The 3D model allows for visual biomedical inventory that can be easily identified in the virtual environment. At present the captured 3D image is accessible from a third-party cloud based software for a subscription fee. A professional 360 image scanning device was used to create the 3D virtual environment which was easily operated by a single person to scan the building, room to room and floor to floor until all the building floor plans

Figure 1: Cytopathology Department Dollhouse View using Matterport technology.

Figure 3: Print screen of a Virtual Environment of a lab room

Figure 4: Examples of asset tagging and descriptions (biomedical assets)

Figure 5: Asset inventory list in virtual tour format with search box

were covered. A third-party cloud-based software accessible through subscription was used to convert the image into an interactive Virtual Environment (VE) model. A sample VE screen shot is shown in Figure 3. The software artificial intelligent capability can identify objects in the rooms, stitch all the room scans together and reconstruct the space into an immersive virtual tour while allowing users to add more content such as digital tags with texts, links and videos.

The tagging feature in Matterport enhances virtual tours functionality with customisation options, making them more informative and engaging for users. Users can easily access the tagging feature in Matterport by clicking on the tag icon on the virtual tour screen. The tags can include descriptions and relevant information about the object or area, such as the type of asset, the registration number of the asset, its model, and its serial number as shown in Figure 4. The tagging feature is a useful tool for BE asset management as it allows for easy identification and tracking of assets as well as maintenance needs. Search box is also provided in the VE interface to allow users to search for a particular asset or location quickly as shown in Figure 5.

Apart from that, a questionnaire link was distributed to stake holders and facility management team to get their feedback on application of 3D virtual environment technology in BE asset management. Based on the survey results shown in Figures 6 (a) and (b), the majority of respondents found that the 360 image-based virtual tour usage in BE management to be useful and valuable. Most respondents agree that the technology provides multiple benefits in improving facility management which includes BE assets. The high level of user acceptance suggests that the application meets or exceeds user expectations and provides meaningful benefits for BE management. The majority of respondents agree that VE could greatly enhance maintenance and repairs of BE assets as well as allow the training of a maintenance or repair team in a virtual environment.

Conclusion

The development of a 3D virtual environment model for BE maintenance aims to improve operation and management of hospitals while providing economic and effective options for onsite or off-site facility managers, engineers, medical planners, or asset management team. Pilot VE model of the Sarawak General Hospital Cytopathology unit provides valuable insight into the feasibility and acceptability of such technology. 3D virtual environment imaging technology such as Matterport has the potential to revolutionise BE maintenance by providing accurate and up-to-date information on assets, enabling more efficient and effective resource allocation. Feedback from stakeholders such as administrators, engineering facility managers, engineering team, medical planners or asset management team have shown a high acceptance rate. Survey results also demonstrated that most users are

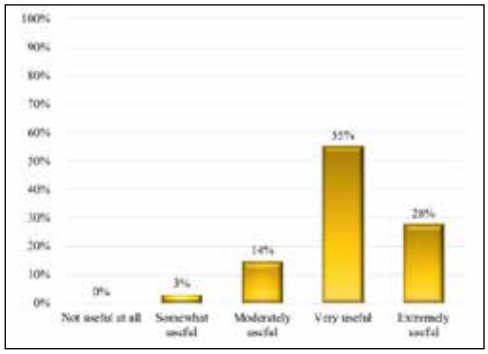


Figure 6 (a): Feedback on the level of usefulness of 360 image-based VE Application

Figure 6 (b): Maintenance team feedback on the benefit of VE Application in BE operation maintenance

highly contented with the benefits provided by virtual tours technology, including improved asset management, verification, streamlined inspections, enhanced communication, better decision making, and improved safety. ■

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