Living with a Digital Twin: Operational management and engagement using IoT and Mixed Realities at UCL's Here East Campus on the Queen Elizabeth Olympic Park

Oliver Dawkins*[1], Adam Dennett†[1] and Andrew Hudson-Smith‡[1]

[1]Centre for Advanced Spatial Analysis (CASA), University College London,
Gower Street, London, United Kingdom

January 12, 2018

Summary

The concept of Digital Twin is becoming increasingly popular with researchers and professionals in the AEC industries as a means of visualising, modelling and working with complex urban systems. This is achieved through the coupling of physical systems with comprehensive digital representations that automatically update to match the state of their physical counterpart. Using real-time data from IoT technologies and advanced 3D visualisation this research conducts a practical investigation into the process of creating and working with a Digital Twin of the new UCL Campus at Here East on the Queen Elizabeth Olympic Park.

KEYWORDS: Digital Twin, Internet of Things, Real-Time Data, 3D Visualisation, Mixed Realities

1. Introduction

The concept of 'Digital Twin' refers to the coupling of a physical system with its digital representation in a computer such that any relevant change of state in the physical system is detected and triggers a flow of data that causes a corresponding change in the state of its digital counterpart. New information generated by the Digital Twin can then be fed back into the physical system through direct actuation or through visualisation for users who may intervene. The metaphors of 'mirroring' or 'twinning' are used to convey the mutual alignment and reciprocity between the physical system and its digital or virtual counterpart (Grieves, 2017). In this way such technologies offer a powerful and responsive means for modelling complex dynamic systems to inform decision making.

In the recent report 'Data for the public good' the UK's National Infrastructure Commission (NIC) proposed the creation of a 'Digital Twin' to unify the management of data concerning transport, rail, power, water and communications infrastructures alongside meteorology and demographics across the whole of the UK (NIC, 2017). In October 2017 the NIC held their Digital Twin Challenge giving teams the opportunity to build a Digital Twin of part of the city of Bristol. In response the UK's Ordnance Survey have proposed that '"Digital Twin" is the new "Smart City"' (Morley, 2017). The Bartlett Centre for Advanced Spatial Analysis (CASA) already has experience in this field having created their own Digital Twin Environment (DTE), ViLo, in collaboration with the Future Cities Catapult.

* oliver.dawkins.13@ucl.ac.uk
† a.dennett@ucl.ac.uk
‡ a.hudson-smith@ucl.ac.uk

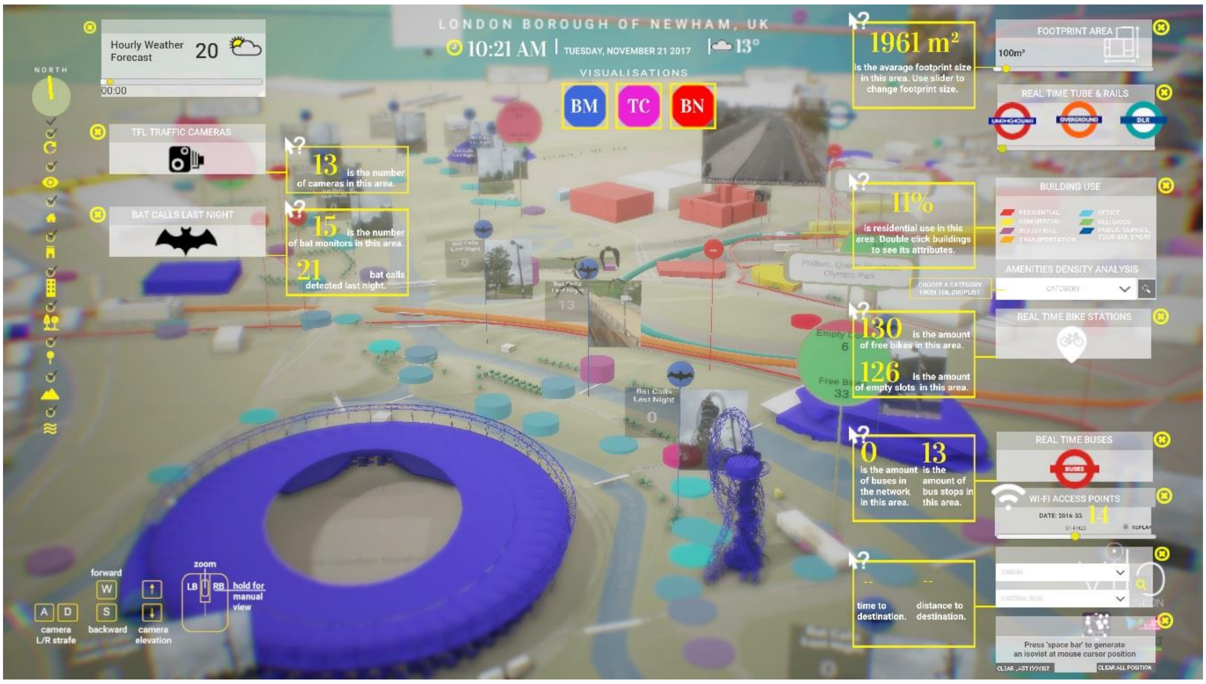

Figure 1 ViLo: The Virtual London Platform by CASA

2. Background

While the provenance of the term 'Digital Twin' is unclear, Grieves (2017) attributes the underlying concept to his own work in the development of Product Lifecycle Management (PLM) methodologies at the University of Michigan in the early 2000s. Within the context of industrial design and manufacture the idea that unites Digital Twin with his earlier concepts of the 'Mirrored Spaces' and 'Information Mirroring Models' was that all of the relevant changes to a product would be tracked throughout its entire lifecycle: from initial design through to manufacture, operation and its eventual disposal.

Despite claims for the novelty of this concept there are earlier precedents. In 1991 Yale computer scientist David Gelernter proposed the notion of 'Mirror Worlds': computer generated models of urban regions in which 'the *whole city* shows up on your screen, in a single dense, live, pulsing, swarming, moving, changing picture' (Gelernter, 1991 p. 30). The value of Mirror Worlds derive from their ability to provide holistic views or 'topsight' of the wider urban ensemble, while also enabling the user to 'dive deeper' into the data while retaining its spatial context.

CASA's ViLo provides this kind of topsight by integrating a custom map and terrain tiling system with detailed 3D models of buildings that can be served dynamically from a dedicated database. Further contextual information can also be obtained from websites like Wikipedia or Foursquare, linked to the 3D models, and interactively queried. Urban dynamics can also be visualised in near real-time by accessing a range of application programming interfaces (APIs) such as those provided by TFL and Twitter. These provide timely information on environmental conditions; location, availability and progress of public transport; and further context about spatio-temporal patterns of activity through citizens' interactions with social media.

Less fully developed in ViLo is the ability to drill down through the data to observe interactions at lower scales. Currently it is possible for the user to click on a 3D model of a building to query it and find out more information. But what if users want to see more detail about the buildings construction, or even take a walk around inside it? Intuitively each Mirror World is an aggregate of smaller scale objects like buildings, streets, trains, buses, cars, each of which could feasibly have their own Digital Twin, each itself a complex aggregate of further sub-components.

In relation to the built environment there is an affinity between the aspirations of Digital Twin and those of Building Information Modelling (BIM). In architecture, engineering and construction projects BIM provides an integrated digital environment for the management of three-dimensional data to support collaboration between stakeholders (Garber, 2014). Upon delivery of the project, the BIM models are expected to be transferred to the site owners, and passed down to facility and asset managers (Boyes, Ellul and Irwin, 2017). Where such data are not available a ‘scan-to-BIM’ process of generating geometry and associated semantics from LiDAR might be used to capture and reconstruct this information after the fact (Ellul et al., 2017). This can then be used to support integrated and data-driven approaches to ongoing maintenance and operational management of the site (Deutsch, 2015).

3. Digital Twin at Here East

Here East is a new centre for innovation in business, technology, media and education located on the Queen Elizabeth Olympic Park in East London. Occupying the media centre created for the 2012 London Olympics, the site now houses studios for BT Sport, the Infinity data centre, the Plexal innovation hub for small enterprises, and two new campuses for Loughborough University and UCL.

Figure 2 Here East Digital Twin application prototype (front view)

As students move in to UCL’s newly completed campus this study investigates how BIM and LiDAR data can be combined with real-time data from an array of IoT sensors, and the site’s Building Management System (BMS), to create an operational Digital Twin. Unlike previous studies where sensor enabled buildings have been studied in isolation (Dublon et al., 2011), this study considers the relation between the building and its wider environment, both physical and social. This is investigated through an integration with CASA’s ViLo model of the Olympic Park, enabling further research into the challenges of integrating real-time data, the transition between different spatial and temporal scales, and the level of abstraction this requires. This study also provides the opportunity to consider what it will be like in the future to live and work with Digital Twin technology on a daily basis, and what impact it might have on human behaviour. We do this by providing opportunities for staff, students and visitors to interact with that Digital Twin.

4. Methodology

For this study 20 environmental sensor boxes will be installed in the UCL campus at Here East. The initial experiment will run for a duration of six months from February to July 2018. The data obtained will be used to perform longitudinal analysis which seeks to identify patterns and relationships between environmental parameters over time. Access to data from the Here East's BMS will be sought for the purpose of cross-correlation with sensor outputs in order to test their ability to provide additional intelligence for sustainable operational management.

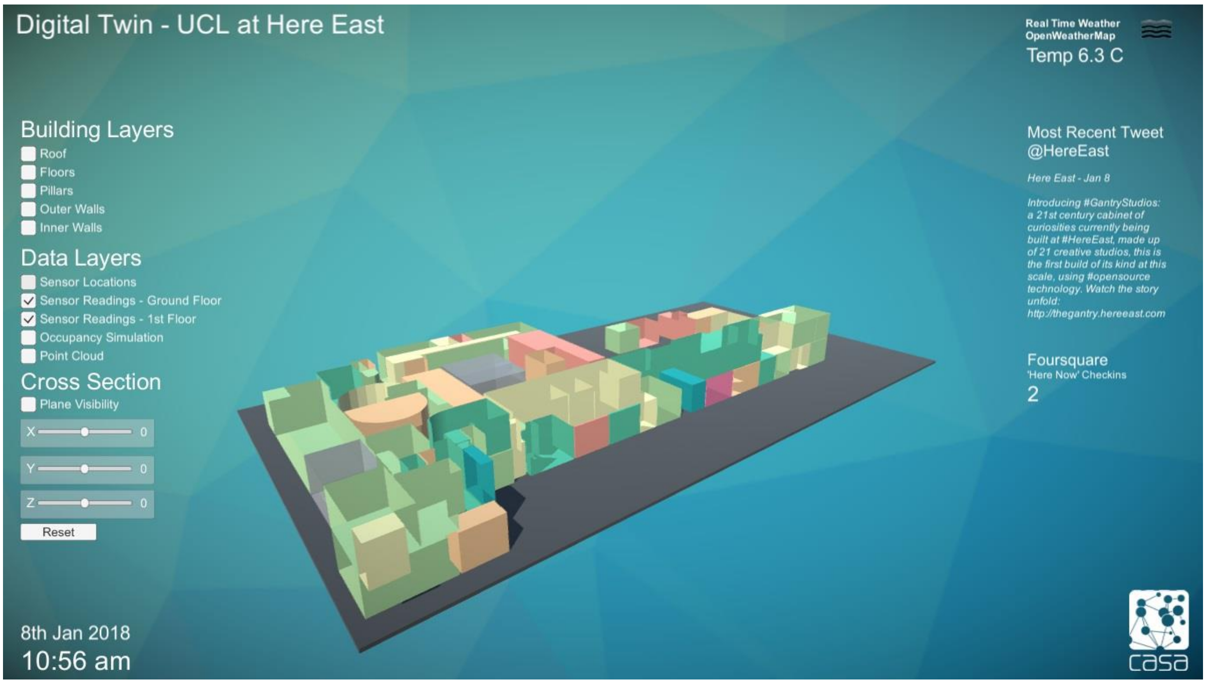

Figure 3 Example of a dynamic data visualisation

Visual analysis of the data will be enabled in three dimensions and near real-time by leveraging the rendering capabilities of the Unity game engine. This enables timely visual inspection of otherwise invisible aspects of the building's daily performance. To provide visual context we propose constructing a 3D model of the site from BIM data, secured from the construction process, and LiDAR data captured in collaboration with the Bartlett scan group (Bscan).

4.1. ICRI Sensors for real-time environmental data

The 20 sensor boxes being used in this study were created by the Intel Collaborative Research Institute for Urban IoT (ICRI). Each box is equipped with Texas Instruments CC2650STK sensor tag which has been programmed to capture separate readings for temperature, humidity, barometric pressure and ambient light levels once every 60 seconds. The readings are then processed by an Intel Edison which posts them to the OpenSensors platform for open IoT data. The Edisons, programmed with Python, will connect to the internet via the Olympic Park's WiFi network. These components are housed in robust weather proof boxes, originally designed for outdoor deployment.

Figure 4 ICRI Environmental Sensor Assemblies.

4.2. Beacon technology for engagement and participation

In order to invite interaction with the Digital Twin the sensors will be presented in the form of an exhibit. Interaction with the Digital Twin will be enabled using Google beacon technology embedded within each sensor box. These provide a link from a physical object, the sensor box, to online resources which can be accessed via mobile devices and can include links to the 3D representation of the Here East Digital Twin.

5. Conclusion

By establishing this link between the user and the Digital Twin we hope to ensure that living and working with the Digital Twin will be a more immediate and participatory experience in the future. Through multimodal interaction, enabled via the web browser, virtual reality (VR) and augmented reality (AR) technologies, we aim to further enhance this experience and demonstrate the potential for more participatory and 'positive virtualities' in the built environment (Batty and Hudson-Smith, 2005).

6. Acknowledgements

This research is funded by the Engineering and Physical Science Research Council and the Ordnance Survey. We also thank PETRAS for additional support, and the ICRI for use of their sensors.

7. Biography

Oliver Dawkins is a PhD Candidate at the Bartlett Centre for Advanced Spatial Analysis (CASA). Oliver's research uses mixed reality interfaces and real-time data to support urban decision making and communication. Oliver is also an associate member of the Intel Collaborative Research Institute for Urban IoT

Professor Andrew Hudson-Smith is Director of Centre for Advanced Spatial Analysis (CASA). Andrew holds a Chair in Digital Urban Systems and is Editor-in-Chief of Future Internet Journal. He is also an elected Fellow of the Royal Society of Arts, a member of the GLA's Smart London Board and a member of the EPSRC Board for the Digital Economy stream.

Adam Dennett is a Lecturer and Deputy Director of the Bartlett Centre for Advanced Spatial Analysis (CASA), University College London. He is a geographer, graduating with a degree in Geography from Lancaster University in 2001, then an MA and PhD from the School of Geography, University of Leeds, in 2010.

References

Batty, M., and Hudson-Smith, A. 2005. Urban Simulacra: London. *Architectural Design*, 75(6), 42-47.

Boyes, G. A., Ellul, C., & Irwin, D. (2017). Exploring BIM for Operational Integrated Asset Management-A Preliminary Study Utilising Real-world Infrastructure Data. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (Vol. 4, No. 4W5), 49-56.

Deutsch, R. (2015). *Data-driven design and construction: 25 strategies for capturing, analyzing and applying building data.* John Wiley & Sons.

Dublon, G., Pardue, L. S., Mayton, B., Swartz, N., Joliat, N., Hurst, P., & Paradiso, J. A. (2011). Doppellab: Tools for exploring and harnessing multimodal sensor network data. In *Sensors*, 2011 IEEE, 1612-1615.

Ellul, C., Boyes, G., Thomson, C., & Backes, D. (2017). Towards Integrating BIM and GIS—An End-to-End Example from Point Cloud to Analysis. In *Advances in 3D Geoinformation*, Springer, 495-512.

Garber, R. (2014). *BIM Design: Realising the Creative Potential of Building Information Modelling*. John Wiley & Sons.

Gelernter, D. (1991). *Mirror Worlds: or the Day Software Puts the Universe in a Shoebox…How It Will Happen and What It Will Mean.* Oxford University Press. Oxford.

Grieves, M., & Vickers, J. (2017). Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. In *Transdisciplinary Perspectives on Complex Systems*, Springer, 85–113.

Morley, J. (2017). 'Digital Twin' is the new 'Smart City'. Ordnance Survey. [ONLINE] Available at: https://www.ordnancesurvey.co.uk/blog/2017/10/digital-twin-new-smart-city/ [Accessed 12 Jan 2018]