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Work-in-Progress—Interactive Digital Twins in Field Service Operations Training and Real-Time Support

Anasol Peña-Rios [1] and Anthony Conway [1]

[1] BT Research Labs, Ipswich IP5 3RE, UK
anasol.penarios@bt.com

Abstract. Digital Twins (DT) are real-time, high-fidelity, data-driven models that mirror and synchronise with physical or logical assets, processes, or systems. They use data to model and optimise system outcomes before they occur, enabling better-informed decision-making and saving time and resources. Though there are still challenges to be overcome, there are many potential applications of DT for training and support. This paper describes opportunities and challenges as well as introduces a case study based on a work-in-progress Augmented Reality (AR) proof-of-concept application to assist field engineers, aimed at reducing the learning curve for trainees and apprentices and increasing the effectiveness and efficiency of real-time quality control checks in common installation faults towards creating real-time augmented assistance for field engineers.

Keywords: Digital Twins, Augmented Reality, Immersive Training, Field Service Operations.

1 Introduction

Digital Twins (DT) are crucial to digital transformation in various fields. They are real-time, data-driven models that mirror and synchronise with physical or logical assets, processes, or systems [1]. They use real-time data to model and optimise system out-comes, improving decision-making and saving time and resources. DTs connect the original asset or process to a virtual representation, allowing for the modelling and visualisation of outcomes before they occur, leading to better decision-making, im-proved safety, and increased productivity and collaboration.

In education, they have been used to enhance intelligent learning environments (i.e., smart classrooms) [2,3], allowing physical learning spaces to be augmented with multiple capabilities, and in remote labs [4-6] towards creating personalised learning. DTs could help us shape expert systems to identify knowledge gaps and customise education objectives. They can be a valuable resource in training, given that they are modelled on real-world data and behaviour, enabling the simulation of low-frequency events and "if-then" scenarios without health and safety concerns, promoting knowledge generation, and providing decision-making support.

Digital Twins can be implemented differently depending on the use case and primary objective. However, immersive technologies, i.e., augmented reality (AR), mixed reality (MR) and virtual reality (VR), can visually present rich, volumetric da-ta, providing visual confirmation and spatial context, making it easier for end-users to understand what, where, and why the work is required [1].

This paper introduces the case for using digital twins in training and supporting field service operations. Moreover, we present a case study to assist telecom field engineers using a work-in-progress AR application. The application uses AR to label telecom equipment, highlighting its various parts. In addition, it shows step-by-step instructions to complete tasks. The rest of the paper is structured as follows: Section II introduces related work, whereas Section III describes our case study, and Section IV presents a discussion on benefits, challenges, and limitations. Finally, Section V offers conclusions and future work.

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2 Literature Review

2.1 Overview of Digital Twins

Digital Twins (DT) aim to reproduce their counterparts as realistically as required for their intended uses. Creating intelligent environments that combine field devices, machines, production modules and products that autonomously exchange information, trigger actions, and control each other independently reduces the lines between the real and digital world [7]. While the concept is no longer new, it has generated growing interest over the last few years, mainly as it is increasingly seen as a critical enabler of digital industries. This happens in manufacturing and other areas, such as services and education.

2.2 Adoption of Digital Twins in Education and Training

There are three stages of knowledge acquisition: introductory, advanced, and expert [8]. Constructivism-oriented learning environments are most effective for advanced knowledge acquisition, allowing individuals to create knowledge based on experience [8, 9]. More objectivistic approaches better support initial knowledge acquisition. However, transitioning to constructivist approaches as learners gain more knowledge and provide them with the capabilities to deal with complex and ill-structured problems [8, 9]. Digital Twins have the potential to support education and training by using models based on real environments and therefore supporting constructivist approaches towards advanced/expert knowledge acquisition.

An example of Digital Twins (DTs) in education is remote and virtual laboratories using a digital twin of equipment. Students play an active role and have a substantial experience reinforcing their learning [10]. In remote environments, the students control the equipment through teleoperation. In virtual environments, they work with simulations based on the modelled asset or process. This aligns with the humanist theory of learning, which is learner-centred and emphasises that people naturally tend to learn [10]. The experience provided by the digital twin acts as a catalyst for the learning process. Laboratory activities are similar to training tasks, concentrating on skills development and practical application.

2.3 The Potential of Using Immersive Technologies for Digital Twins

Immersive technologies refer to all virtual and physical crossing environments, creating a feeling of 'being there' or immersion. This encompasses augmented reality (AR), mixed reality (MR) and virtual reality (VR). Given these technologies' capabilities to present complex data in a spatial context, they are better suited for real-time on-the-job assistance and training scenarios.

AR and MR can enhance human interactions with DTs, merging real and virtual objects via interactive data visualisation using real-time information [11]. These enables task guidance with the help of a (remote) domain expert or guided by an AI-based expert system (Fig. 1) [12]. Moreover, they can enable remote control and diagnostics using DT's bi-directional communication capabilities.

VR enables interaction with the virtual element of a DT modelled on real-world data, allowing the user to test different scenarios in a safe environment [13]. This can be used for training using simulated scenarios to recreate everyday situations and low-frequency events. In addition, given that the DTs are modelled to simulate real-world behaviour, it would be possible to configure equipment based on different requirements, test them in VR, and transfer the final configuration to its physical counterpart when a specific goal is achieved.

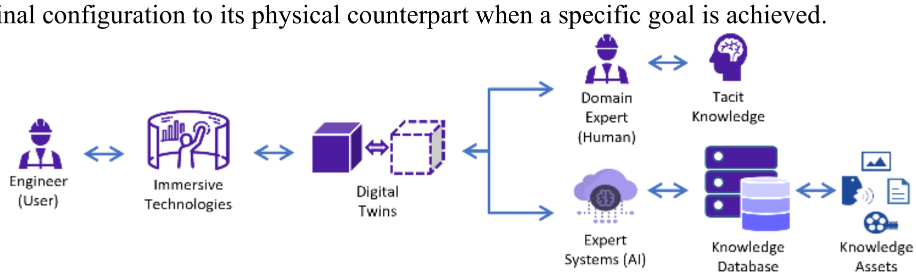


Fig. 1. Immersive Tech and DTs Interactions in Training and Real-Time Support.

3 Case Study: An Augmented Reality Application for Field Service Telecom Engineers

Training specialised workers is a high cost in any business. The increasing complexity and number of underlying technologies and equipment variants make it difficult to keep the workforce up-to-date. The challenges include quickly onboarding new workers and effectively transferring and maintaining organisational knowledge. The risk of losing crucial knowledge when expert employees leave the organisation, such as due to the retirement of ageing workers, is a concern.

To tackle some of these challenges, we have modelled a one-way digital twin of the Customer Splice/Service Point (CSP) that aims at:

- Reducing the learning curve for trainees and apprentices.
- Improve the holistic knowledge across all field engineers.
- Increase the effectiveness and efficiency of real-time quality control checks.
- Improve data collection on field engineering tasks and common installation faults.

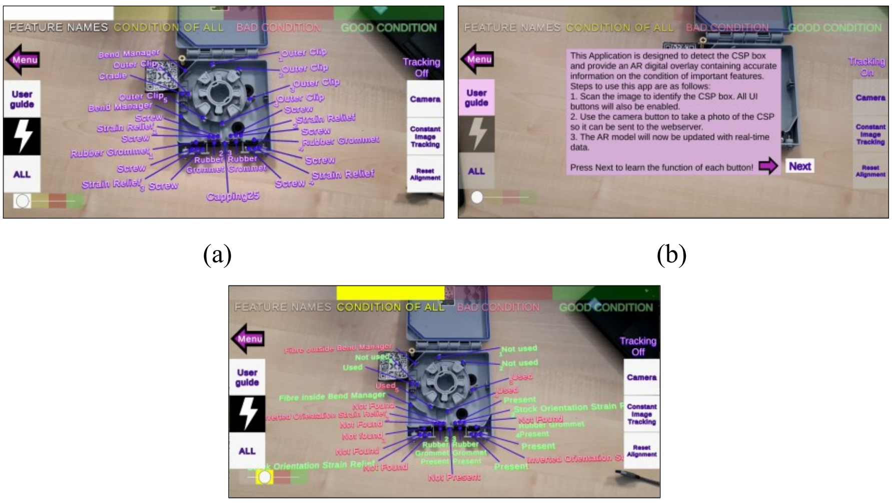
A CSP is a fibre distribution box installed outside customer premises by field service engineers to deliver high-speed broadband and other fibre services. For engineers to access the CSP digital twin information, we developed an AR application for mobile phones that shows CSP's installation-related information to support engineers with hands-on training. Moreover, using a mobile phone camera, the app identifies and highlights common mistakes on the device's installation.

3.1 Learning Activities

The AR application was developed as a proof of concept to show the potential for using DTs to create an augmented assistant for field engineers (Fig. 2). To do so, we modelled the CSP to create a one-way DT [14], obtaining information of the physical device in real-time via the mobile's camera. The app includes three activities designed for a specific learning activity (Table I). Activities are not timed, and they can be started in any order.

Table 1. Table captions should be placed above the tables.

ID	Activity	Type
1	Introduction	Training
2	Task	Training
3	Evaluation	Real-time support



(a) (b)

(c)

Fig. 2. Screenshots of the application showing: a) Equipment parts. b) Step-by-step instructions. c) Task evaluation.

3.2 Implementation

The application uses a QR code and image tracking to detect the object in a 3D coordinate system, enabling the creation of the AR layer and displaying information about its parts. It was built as a mobile app using Unity

2020.3, ARFoundation 4.2 [15] and ARCore 4.2 [16]. The application was tested in two mobile phone models, a Samsung Galaxy A40 and a Samsung Galaxy S8+. The S8+ performed much better in multi-core and single-core, given that multi-core performance is linked with the device's graphical performance.

4 Discussion

Digital Twins (DTs) support constructivist approaches, which are effective for advanced stages of knowledge acquisition. They offer numerous benefits to training, such as allowing trainees to have personalised, immersive learning experiences, promoting better-informed decision-making, and improving safety and productivity.

However, there are also limitations and challenges associated with using DTs in training. One challenge is the cost of developing and maintaining these high-fidelity models, which requires specialised expertise and resources. Another challenge is ensuring the data used to build DTs is accurate and up-to-date, which can be difficult to achieve in real-time. Finally, it is essential to integrate technology to create practical learning experiences and foster participation, collaboration, creativity, and engagement seamlessly. Achieving this requires knowledge that spans many topics, including ubiquitous computing, artificial intelligence, learning sciences, immersive technologies, and human-computer interactions.

Despite these challenges, using DTs in training offers numerous opportunities for innovation and improvement. For example, DTs can provide a platform for remote learning, which can be especially beneficial in locations with limited access to specialised equipment or facilities. They can also help onboard new employees more quickly, reducing the risk of loss of institutional memory. By leveraging the potential of DTs, the education sector could create immersive and engaging learning experiences that support trainees' success and advance their careers.

5 Conclusion and Future Work

The paper provides an overview of the use of Digital Twins in education and training, presenting a work-in-progress augmented reality application for training and real-time support of field service telecom engineers. The objective of the case study is to show the benefits, limitations, and challenges of DTs in training. Currently, only qualitative feedback has been collected, and the results have been positive, with the application showing potential to support knowledge transfer for field engineering activities.

Our future work includes conducting a user study with field engineers of varying levels of expertise to validate the findings and evaluate the app's usability. Our final aim is to implement a multi-platform device-agnostic experience using different immersive technologies. The proof-of-concept app demonstrates the potential of combining AR and machine learning to create a real-time augmented assistant for field engineers. The study aims to provide a deeper understanding of the potential and limitations of DTs in education, particularly in industry-oriented training.

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