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Augmented Reality with Industrial Process Tomography: To Support Complex Data Analysis in 3D Space

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ABSTRACT

Today, in-situ analyzing and monitoring are imperative for ensuring successful and healthy industrial processes in confined environments. With the rapid development of digitization, augmented reality (AR) has been utilized for letting people immersively interact with the necessary information. However, there are still knowledge gaps between AR technique and domain users pertaining to effective analysis of complex data. Hence, new solutions empowering domain users would benefit the whole industry. In this study, we report an initial prototype supporting complex data visualization and analysis in entire 3D surroundings within industrial process tomography (IPT). Microsoft HoloLens 2 is equipped for users to interact with the 3D information characterizing the workflow of the industrial process with high immersion. Our work distinctly improves the performance compared to existing solutions, pointing the way towards how AR should be deployed and developed more efficiently for aiding IPT systems.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in collaborative and social computing*; **Human computer interaction (HCI)**; **Mixed / augmented reality**; **Visualization systems and tools**.

KEYWORDS

mixed reality, immersion, 3D surroundings, data visualization, industrial process tomography

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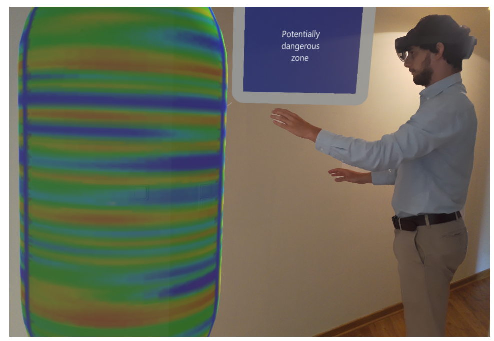

Figure 1: User interacts with 3D complex data presentation.

1 INTRODUCTION AND RELATED WORK

Augmented Reality (AR), a derivative from Virtual Reality (VR) technique whereby the virtual objects are overlaid in the real environment [1], is one of the cutting-edge technologies being applied in various fields such as medicine and education [2]. For industry, there is still a gap between AR technique and industrial application, resulting in AR not being more extensively-used [4]. However, on the premise that it has the capacity to offer the interactive interfaces of displayed digital content, while bringing users to immersively communicate and interact with the virtual objects, AR has already been deployed in some practical industrial aspects [3, 5, 7].

Industrial process tomography (IPT), as a widely used non-intrusion imaging technique, has effectively demonstrated its high value in industrial process monitoring and product quality control [11, 12]. Electrical Capacitance Tomography (ECT) is a specific mechanism to monitor processes in confined containers, with no access to the internal content of the targeted vessel [10]. Complex data analysis always requires efficient reproduction of the measurement regarding the reconstructed images by ECT to reveal the material distribution inside the closed containers [6]. It is critical to observe and analyze the images which imply the state of the process flow, supported with tomograms and graphs, in a protection-friendly manner without any direct interference with the on-going industrial process [9]. Therefore, getting domain users instant access for implementing in-situ data observation and analysis becomes the main concern of this paper. Hereby, we propose a novel AR solution for IPT users to interact with complex data by eliciting the immersive and tangible 3D surroundings.

Although exploiting Mixed Reality (MR) in IPT systems is still scarce, some research has already pioneered the usage of AR to benefit the data analysis for industrial tomographic users [9, 13]. At the beginning of this century, Mann et al. [8] brought an AR methodology so as to visualize the mixed fluid in stirred chemical reactors by using ECT. Recently, Nowak et. al [9] demonstrated a proof-of-concept study regarding ECT, by developing a new AR solution to underpin the onsite analysis of complex numerical data through mutual collaboration. In our study, we propose a updated solution based on Nowak's [9], to help users investigate more complicated data which are represented as images or graphs in a more immersive and interactive 3D environment.

2 PROPOSED SOLUTION

2.1 System Features

The proposed system is manifested as an interactive application in line with AR/MR technique to support domain users for in-situ ECT data analysis. The practical application is capable of displaying a variety of visualized data especially in 3D format, characterizing the workflow of the carried industrial process. During implementation, users are requested to be equipped with the up-to-date Microsoft HoloLens 2 (the link), a convenient and portable headset which provides the most comfortable and immersive experience for AR/MR.

2.2 Initial application

The main goal of our prototype is to provide users with an entirely immersive experience to interact with the ECT complex data in a 3D surrounding. By using Microsoft HoloLens 2, users are enabled to observe, interact, and analyze different 2D and 3D graphical information from the original source. An example of data in a raw format browsed through the headset is displayed in Figure 1. Then, the combined formats of the complex data such as graphs or plots, followed by the ultimate 3D reconstructions of the process are presented to the users. All the virtual objects are shown as holographic artifacts floating around, which makes users able to manipulate, move, scale, and rotate them with hands in this completely immersive environment, as elaborated in Figure 2.

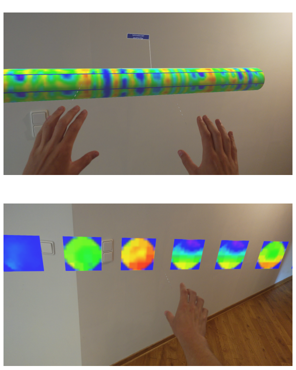

Figure 2: User works with different forms of data visualisation. Left: 3D tomogram data visualisation, Right: raw data frames representing different flows over time.

3 DISCUSSION

Novel tools and applications are desirable for industrial ecosystems. New cutting edge technologies will enhance humans' performance within industrial domain. We strongly believe that shifting the working environment from flat 2D screens to stereoscopic 3D space can immerse users more deeply into the context which enhances the working efficiency. However, we acknowledge that there are still some limitations in our solution. First, we have to realize current hardware limitations, such as available computing power, battery capacity, device weight, and field of view will have observable impact on potential applications. Also, it may initially be difficult for users to adjust to our new AR system, where they are requested to become familiarized with all the application details. Last but not least, we have not yet tested our solution regarding rigorous human aspects, which is obligatory for a human-in-the-loop technique.

4 CONCLUSIONS AND FUTURE WORK

In this study, we present an early-stage prototype enhancing immersion for complex data analysis for IPT experts using AR technology in an entire 3D space. Our novel solution uses the newest AR/MR headset, Microsoft HoloLens 2, which facilitates displaying different formats of data – from raw ECT data frames, through processed graphs and plots, and finally complex 3D representation related to specific IPT processes. Currently our app is under further development and is not ready to be tested in real life scenarios. For future work, we will identify the following features: voice commands to control virtual environment, shared experience allowing users for mutual collaboration on the spot, and connecting data streams from sensors to have in-situ preview, which will all be implemented with a more comprehensive experiment with distinguished IPT experts.

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