Effect of Augmented Reality and Virtual Reality in Crime Scene Investigations

Meshal Albeedan
School of Computer Science and Mathematics, Liverpool John Moores University, L3 3AF, Liverpool, United Kingdom
M.A.Albeedan@2019.ljmu.ac.uk

Hoshang Kolivand
School of Computer Science and Mathematics, Liverpool John Moores University, L3 3AF, Liverpool, United Kingdom
H.Kolivand@ljmu.ac.uk

Ramy Hammady
School of Computer Science and Electronic Engineering, University of Essex, CO4 3SQ, Colchester, United Kingdom
R.Hammady@essex.ac.uk

***Abstract*—This research delves into the transformative potential of Augmented Reality (AR) and Virtual Reality (VR) in elevating the field of forensic science. Titled "Revelotinaising Forensic Science with the use of Augmented Reality and Virtual Reality," the study primarily focuses on leveraging HoloLens technology to aid crime scene investigation, addressing the challenges posed by limited time and geographical variations among colleagues. By exploring contemporary techniques for storing, visualizing, and manipulating evidence, the research seeks to equip forensic investigation units with advanced technological tools. In a landscape where law enforcement increasingly adopts forensic techniques, the paper underscores the significant role played by forensic scientists in criminal investigation, civil litigation, and disaster response. It highlights the importance of teamwork and innovative investigative tools like GPS positioning, video imaging, and data mining in the success of crime scene investigations. The integration of tri-dimensional (3D) representations of objects and the recognition and preservation of physical evidence are emphasized as key aspects of efficient crime-solving. Furthermore, recent studies on the application of AR for collaboration among crime scene investigators are explored, showcasing how AR technology fosters consensus-building within investigative teams. The distinction between VR and AR, with the former immersing users in a wholly digital environment and the latter enhancing the real world with digital elements, is elucidated. This paper serves as a comprehensive exploration of the integration of AR and VR in crime scene investigations, promising to revolutionize the field of forensic science. It sets the stage for further research and development in leveraging these technologies to enhance crime-solving capabilities and facilitate more efficiency.**

Keywords—Crime scene, Crime scene investigations, Augmented reality, Virtual Reality, Forensic science and new technologies

I. Introduction

The review of relevant literature in this study explores the use of Mixed Reality (MR) and augmented reality (AR) technologies, particularly Microsoft HoloLens, in crime scene investigation. Teo et al. [1] introduced an MR system that leveraged 360 panorama images within 3D restructured scenes to enhance remote collaboration, allowing users to switch between various 360 scenes, thereby improving spatial understanding and interactivity. Prilla and Rühmann (2018) emphasized the significance of MR devices in providing advanced means for analyzing users' movements, behaviour, and interactions with digital objects, highlighting their unique features not found in other tools.

Spain et al. [2] focused on human factors research, aiming to develop and apply virtual environments (VE) across various contexts. Brown and Prilla [3] evaluated the usability and preferences of AR devices for remote consultations, noting participants' varying preferences despite similar usability scores. Speicher et al. [2] explored the potential of 360 videos for multi-user collaboration in remote settings and introduced "360 Anywhere," a video framework supporting collaborative AR applications. Kolkmeier et al. [4] examined remote MR collaborative systems, emphasizing core design areas for experts providing real-time support.

Rühmann et al. [5] developed a computer-generated 3D analysis tool for MR with Microsoft HoloLens, focusing on cooperative support situations. Poelman et al. [6] presented an MR system for crime scene investigation that enabled spatial collaboration between investigators and remote experts using head-mounted displays. Ma et al. [7] utilized 3D animation to visualize crime scenes accurately, particularly for courtroom presentations, reconstructing crime scenes using computer techniques and emphasizing its applicability for various types of crimes.

These studies collectively contribute to the understanding of how MR and AR technologies, including Microsoft HoloLens, can enhance crime scene investigation, remote collaboration, and the visualization of crime scenes, with each study providing unique insights into the application and benefits of these technologies in forensic contexts.This paper aims to outline the methodology used in our study, which focuses on creating a systematic mixed reality (MR) application using Microsoft HoloLens 2 to assist police officers. We detail our research methods, including research design, paradigm, approach, data collection, sampling, analysis, limitations, and ethical considerations. Additionally, we describe theoretical frameworks and crime scenario prediction models. Our research employs both qualitative and quantitative phases, with primary data collection. We present fourteen hypotheses to achieve our study's objectives.

- The analysis tasks include:
- Conceptual design of Mixed Reality crime scenes.
- Development of a prototype MR learning environment App and graphical user interface.
- Establishment of research models, paradigms, and approaches.
- Evaluation of the model and parameter tuning.

- Integration of the app on HoloLens and monitoring of police training for advanced crime scene investigation.
- Implementation of data collection and sampling.

II. User-Centred Design

This study adopted a user-centred design (USD) model to better understand user needs and preferences regarding product features. Thus, USD was applied to better understand crime scene investigation processes and the features of the MR application.

As demonstrated in Figure 1, it begins with the project's start, which leads to user research and analysis. This is followed by the concept design stage and prototype testing. It is a test build used to set the context and design. After the sample is tested, a detailed design is formed, developed and measured based on potential performance. After the testing and prototyping are completed, the project is launched. The idea is to ensure that a sound sample is tested and refined in the next phase to reach the project launch [8]

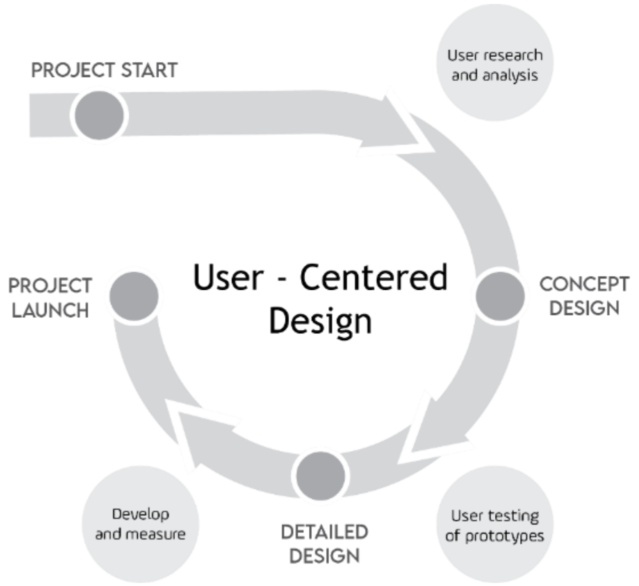

Fig. 1. User-Centred Approach (Kutsyi, 2020)

The purpose of this study is to aid police officers in being more effective in managing crime investigations via an MR application that uses Microsoft HoloLens 2. The main intent of the project is to improve communications and interactions with investigators so that they can execute highly accurate and efficient investigations. In addition, the project is also set to improve the prediction of crime scene scenarios. This research aims to understand the benefits acquired from the domain of MR applications, which entails updating the archival system via 3D scanning, thereby creating an interactive crime scene so that the investigation can improve and training for police officers in Kuwait can be enhanced.

III. Extended TAM

The Extended Technology Acceptance Model (e-TAM) expands upon the traditional TAM model by incorporating social influences and cognitive factors. In essence, adopting new technology involves additional processes beyond the traditional TAM, influencing users' intentions over time.

While the TAM emphasizes ease of use as a key factor in technology acceptance, the e-TAM underscores that usefulness has its own determinants. It includes elements beyond ease of use, emphasizing the personal and subjective aspects of technology usability. These determinants encompass perceived interactivity (PI), immersion (IM), and mobility (MOB) within the cognitive realm.

The Theory of Reasoned Action (TRA) examines the relationship between attitudes and individuals' actions, helping predict technology usage. TRA considers personal attitudes and intentions as determinants of technology adoption.

The e-TAM is particularly relevant for technologies used voluntarily, as it focuses on subjective intentions and perceptions. It highlights the potential benefits of technology in improving individual or group outcomes, such as a police officer using mixed reality (MR) to enhance crime-solving, leading to higher performance and status.

To better understand actual behavioral intention (BI), e-TAM incorporates determinants like output quality, which depends on users' perceptions of technology's usefulness in performing tasks. Positive attitudes toward technology are formed and observed through demonstrability, as implied by people's perceptions.

IV. Theoretical Framework: e-TAM Elements

A. Technology Fit

Task–Technology Fit (TTF): Tailoring technology to the specific needs of police officers in solving crimes, particularly using augmented reality (AR) for efficiency. Failure to align technology with these specific requirements diminishes its usefulness.

Individual Technology Fit (ITF): Ensuring that each police officer can seamlessly use AR in line with their individual processes for crime-solving. Technology must align with these established procedures to avoid adaptation issues.

B. Crime Investigation System

Perceived Interactivity (PI): Crucial for determining technology adoption, PI reflects how users perceive the effort required to manage tasks or solve crimes using AR. High interactivity is essential for AR's effective use.

Immersion (IM): Key to using AR effectively for its intended purpose. IM relates to the depth of user engagement with the technology and its relevance. Higher IM improves output quality and fosters acceptance among peers.

Mobility (MOB): The ability to use technology conveniently and flexibly, regardless of location. MOB enhances technology's relevance and usability for various purposes, ensuring successful outcomes.

C. 2) 3.5.3 PU (Perceived Usefulness)

PU is a core aspect of TAM, denoting how users perceive a technology's utility. If a technology is not seen as useful, it may not garner intent or interest, making usefulness a critical factor in technology consideration and adoption.

D. PEOU (Perceived Ease of Use)

PEOU is influenced by individuals' existing perceptions and frameworks regarding a new technology's ease of use. It can determine whether the technology gains mass interest and becomes the new standard.

E. BI (Behavioral Intention)

BI represents the final aspect of TAM, indicating that if a technology is perceived as easy to use and relevant, it can lead to the formation of behavioral intention. TAM encompasses all crucial features that shape BI.

V. User Research and Analysis

The methodology employed in this study entails the examination and analysis of data collected from the intended user group. In this context, junior investigators from the Kuwait police force were enlisted as participants. The objective is to adopt a pragmatic approach that actively involves investigators, providing valuable insights into the practical application of the technology in real-world scenarios. This approach adopts a case study methodology, incorporating actual cases and involving junior investigators. As described by Crowe et al. [9], case study methods draw upon tangible examples to bridge the gap between theory and real-world applications. Consequently, the utilization of augmented reality (AR) in this study benefits from this case study approach, enabling a thorough exploration of its real-world potential.

VI. Concept Design

The concept design requires acquiring data to understand the practical efforts and training needed for investigation [10]. Based on this, the MR application can be formed and provide real-world scenarios in which the relevance of the application is seen as being used by investigators. The purpose is to understand the use of the application and how it can assist in the investigation of these crimes.

VII. User Testing Prototypes

After the concept design, prototypes need to be tested with relevant experts in the field, such as senior police investigators and experts in UI/UX. Feedback from experts is used to improve the design, which entails changing the design, resolving any glitches, and improving the user experience. Finally, the development and measurement of the application require test users (over 100 police officers) to ensure that it is effective in its purpose.

VIII. Detailed Design

There is a unique framework for predicting crime scenarios and understanding the process of digital investigations (Figure. 2).

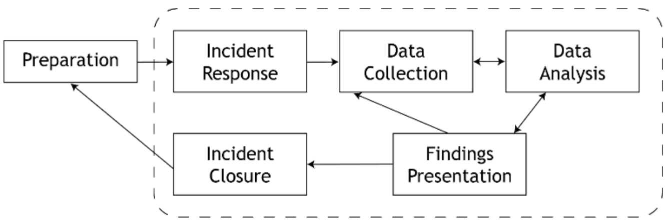

Fig. 2. Unique Investigation Process by Beebe & Clark (2005)

In the system and its application, there is preparation for and a response to the incident. The data are then collected, presented and analysed. The incident is then closed after it is completed. To complete the research, there must be consideration of the literature regarding crime scenario predictions; this is needed in order to conduct the research. Additionally, this entails developing pertinent questionnaires and interviews.

IX. Forensic Investigation Framework

The study methodology involves collecting and analyzing data from target users, specifically junior investigators from the Kuwait police. This practical approach aims to gain insights into the real-world use of the augmented reality (AR) application. It employs a case study method, incorporating actual cases handled by junior investigators, aligning with Crowe et al.'s [9] approach of integrating theory with real-world scenarios.

The proposed change involves inserting a "finding clues" stage between incident response and data analysis. This modification is crucial for improving digital data quality, ensuring accuracy in later stages of data collection and analysis.

Predicting and understanding crime motives is complex and relies on rational cause theory, which examines the motivations behind intentional criminal acts. Technology, particularly AR, aids in crime prediction by analyzing surroundings, faces, number plates, and objects, requiring a meticulous process of finding clues.

AR's 3D imagery expedites data acquisition and analysis, surpassing traditional methods in speed and effectiveness, as technology assists in crime prediction.

Machine learning (ML), as outlined by Lukosch et al. [11], plays a major role in crime prediction using mixed reality (MR). ML leverages past experiences to adapt and improve its predictions, particularly in the data analysis phase of the Unique Investigation Model.

Utilizing MR technology to predict and solve crimes can require increased resources, but it offers potential benefits for law enforcement. Junior investigators can gain valuable experience with technology, contributing to continuous improvement.

Incorporating MR and other productive technologies into crime-solving processes is essential for enhancing overall output and fostering technological advancements.

The research methodology adopts mixed methods, combining interviews and questionnaires to achieve a qualitative and quantitative study [12].

A. Interviews:

Interviews involve structured and unstructured questions, allowing for flexibility in exploring new concepts related to using MR in crime-solving. Experts provided qualitative feedback, offering in-depth insights into the practical application of MR.

B. Questionnaires:

Questionnaires collected quantitative data from a larger sample size, providing statistical insights into MR technology's use in investigations. Closed-ended questions were complemented by open-ended ones for comprehensive feedback.

Primary data collection adhered to ethical considerations, ensuring participants' informed consent, privacy, and comfort. Participants had the option to withdraw at any stage of the research.

The combination of interviews and questionnaires fulfilled ethical requirements, safeguarding participants' rights and privacy.

C. Risk Analysis:

Equipment Failure: While the chances are low, HoloLens equipment failure could hinder 3D crime scene mapping. To mitigate this risk, backup headsets will be available.

DDoS Attack: A denial-of-service attack on the Cloud Repository could disrupt access to records and compromise communications. Mitigation measures include a strong firewall, encrypted data transfer, secure servers, and robust authentication.

Physical Damage: Given the nature of police work, glasses may be damaged. An extra set will be provided to address this risk.

Internet Service Problems: Communication between cloud servers and onsite equipment may be affected by internet service issues. MiFi stations will be provided to ensure reliable internet access in challenging terrains.

These risk mitigation strategies aim to minimize potential disruptions to the use of MR technology in crime-solving.

X. Research Model and Hypotheses Testing

The proposed research model is based on the theoretical foundations of the TAM. The relationships among the constructs in the proposed framework are shown in Figure 3. The underlying assumption is that the BI to adopt a crime investigation MR system is predicted through PU and PEOU, which are determined through TF variables and the MR system. The constructs and justifications for the suggested hypotheses are described in the following subsections.

A. Task-Technology Fit (TTF)

TTF, PU, and PEOU are essential factors in determining the acceptance and use of MR technology for crime-solving. TTF focuses on the alignment of technology with the task at hand, driving perceptions of usefulness and ease of use.

***H1**: TTF significantly influences PU.*

***H2**: TTF significantly influences PEOU.*

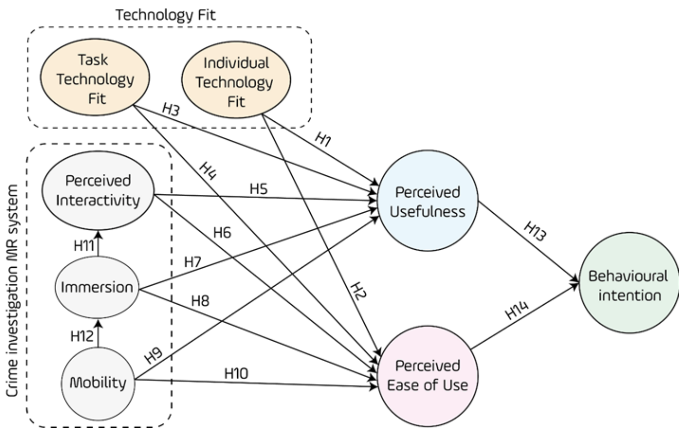

Fig. 3. Proposed Framework

B. Individual Technology Fit (ITF)

ITF, PU, and PEOU considerations delve into the individual preferences and characteristics of police officers when using MR technology. Flexibility and adherence to standards play a role in their acceptance.

***H3**: ITF significantly influences PU.*

***H4**: ITF significantly influences PEOU.*

C. Perceived Interactivity (PI)

PI relates to the interactivity and engagement level offered by MR technology, crucial in determining its usefulness and ease of use.

***H5**: PI significantly influences PU.*

***H6**: PI significantly influences PEOU.*

D. Imaginability (IM)

IM explores the capacity of MR to immerse users in the crime-solving scenario. Its impact on PU and PEOU is examined.

***H7**: IM significantly influences PU.*

***H8**: IM significantly influences PEOU.*

E. Mobility (MOB)

MOB refers to the mobile nature of MR technology, which allows users to employ it in various settings. Its effects on PU and PEOU are investigated.

***H9**: MOB significantly influences PU.*

***H10**: MOB significantly influences PEOU.*

F. Behavioral Intention (BI)

BI represents the intent to use MR technology among police officers. PU and PEOU are crucial determinants of BI.

***H13**: PU significantly influences BI.*

***H14**: PEOU significantly influences BI.*

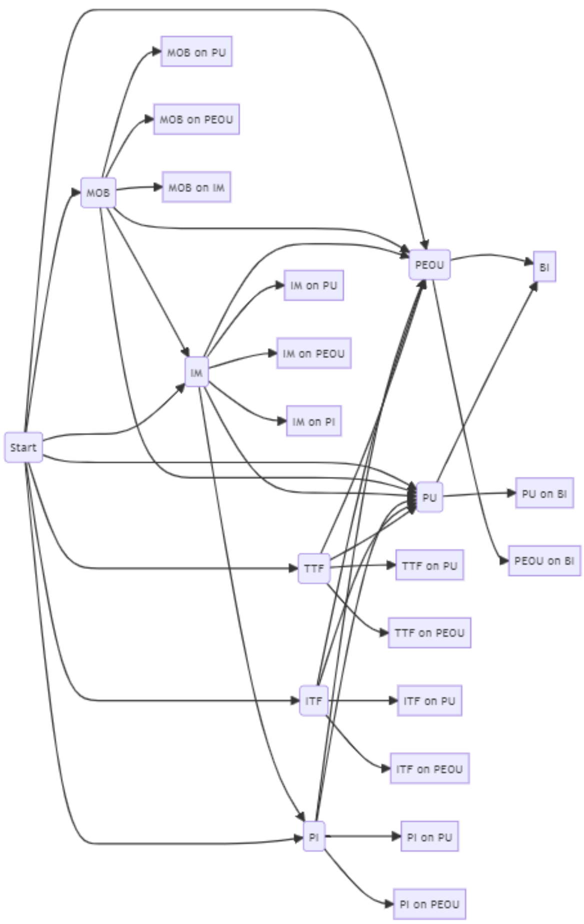

Fig. 4. Illustration of the outcomes

The flowchart represented in Figure 4 visually represents the relationships and hypotheses within your research framework. It starts with the "Start" point and branches into different constructs, including TTF (Task-Technology Fit), ITF (Individual Technology Fit), PI (Perceived Interactivity), IM (Image Management), MOB (Mobility), PU (Perceived Usefulness), and PEOU (Perceived Ease of Use). Each of these constructs is interconnected, reflecting their potential influence on one another. Additionally, the flowchart displays the hypotheses (H1 to H14) that signify the expected relationships between these constructs, providing a clear overview of your research structure and the hypotheses to be tested in your study.

XI. Conclusion

In this study, we conducted a comprehensive review of our research aims, objectives, framework, and hypotheses. To ensure a robust exploration of our research questions, we employed a mixed-method approach that incorporates both qualitative and quantitative research methodologies. Our focus was on the intricately designed theoretical framework tailored for our investigation into crime scenarios. This research framework illuminates the intricate interplay among pivotal constructs, including TTF, ITF, PI, IM, MOB, PU, PEOU, and BI. The research methodology involved conducting interviews with senior investigators and collecting qualitative data from experts at police academies. As a result of our data collection efforts, we formulated and presented a total of fourteen hypotheses to effectively address our research objectives.

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