Computer Science and Information Technologies
Vol. 4, No. 2, July 2023, pp. 160~168
ISSN: 2722-3221, DOI: 10.11591/csit.v4i2.pp160-168

Virtual reality's effects on air crash accident investigation learning interaction

Faisal Othman H Alburaidi, Karl Jenkins, Tom-Robin Teschner
Centre for Computational Engineering Science, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, UK

Article Info

Article history:

Received Jul 29, 2022
Revised May 5, 2023
Accepted Jun 2, 2023

Keywords:

Accident investigation
Air crash accident
Interactive learning
Virtual reality

ABSTRACT

The objective of this study is to gain a deeper comprehension of the factors that play a role in the evolution of virtual reality (VR) for application in the investigation of aviation disasters. This study was motivated by the concept of utilising VR to create an illusion of the procedures involved in an anviation accident. A conceptual model has been presented, to create the scene that will be simple to understand the procedure of accident following an air crash. The idea is to compile a series of steps that an investigation team will go through and then present them in VR. This stage entails obtaining complete views of the object before it crashes and at ground level. This study contributes to the process of creating the groundwork for adopting VR in air crash investigations to provide instructional experiences. The idea that was presented in this research focuses on feature of the surrounding area of the crash or accident, wreckage distribution, wreckage above the ground, wreckage in motion, wreckage at the ground, spatial view effect, and full view projection as the primary VR features that are required for teaching and learning about air crash accident investigations using VR.

Corresponding Author:

Faisal Othman H Alburaidi
Centre for Computational Engineering Science, School of Aerospace, Transport and Manufacturing,
Cranfield University
Cranfield, UK
Email: faisalb21@hotmail.com

1. INTRODUCTION

Due to the fact that one of the benefits of virtual reality (VR) is the capacity to experience a three dimensional (3D) environment rather than a two dimensional (2D) projected environment, this has brought the attention of research bodies to the question of whether or not there is a need for further investigation into the matter. What exactly is it that makes VR so real? [1]. However, the questions of VR impacts are answered following its adoption in on learning outcomes within various educational assessments [2]. Currently a graphical computer that makes use of VR makes it feasible for experts such as engineers to visualise through the use of electronic models that have been constructed [3]. This would be beneficial in offering details behind the structure and system that is being investigated during the phase of development in which the structure and system in question is being evaluated. Typically, users can make use of the VR steps in order to review the internal setup and create the full scheme in an interactive manner. This is all made possible through the VR platform. This has made it possible to design a methodology for quickly laying out a three dimensional arrangement of parts and components, as well as quickly executing drawings and defining the dimensions of manufacturing and assembly.

The fact that there is no general consensus on the concept that is acceptable for the use in learning about air crash investigation with the help of VR is the issue that this research is attempting to address. This

is the problem that is being addressed by this research. The research community has been presented with the challenge of ensuring that they provide some hints or ideas regarding how this could be accomplished as a result of this. That is the reason why the purpose of this research was to accomplish that. The purpose of carrying out this kind of research is to provide users with a better understanding of the real world by simulating VR in order to produce a sense of immersion in the environment that would be beneficial to users. The justification for carrying out this kind of research is found in the fact that this could be done. In a similar vein, experiencing actual life through immersion can make it easier to access and, in some respects, more realistic. This is because it was designed with a certain amount of individualization in the viewpoint and comprehension, which is the reason why it has this effect [4]. This is due to the fact that it makes use of a wide variety of hardware and software configurations in order to present a more all encompassing picture of the problem at hand [5].

Previous research study emphasised the impact that VR has on enhanced learning. Important to this, is the work of Anniballe *et al*. [6], who noticed that there are lack of specific VR applications for enhanced learning of air crash investigation. Additionally, it was shown that there is a widespread absence of correct reporting of accident incidences when the conventional methodology was utilised (that is, the typical method of investigating an aeroplane crash disaster) [7]. Investigators are the individuals who are tasked with the responsibility of identifying all of the debris, photographing it, and labelling it, and this is where the majority of the problems can be found. When conducting an investigation into a plane crash utilising manual processes, there is a considerable chance of making mistakes [6]. This risk increases as the investigation becomes more complex. The question of whether the primary source of the causes of air crashes are man-made or whether air crash accidents are primarily dependent on the structural airworthiness associated with the structural integrity of an aeroplane is another contradictory fact relating to air crash investigations that research tends to ignore [8]. This is yet another contradiction that relates to the investigations of air crashes. A important option that can be presented by VR is to include both man made causes and the structural integrity of an aircraft crash report.

A growing complexity of products and an increase in human errors (e.g., a lack of attention, a misinterpretation, or a bad judgement) in industries have led to an increase in accidents [9]. It is possible to employ VR technology in a range of aeronautical applications. Annotation, visualisation, manufacturing, path planning, air crash investigation, safety assessment, workforce training, skill transfer, and military training exercises within the air force are just a few examples of these applications in use today [10]. VR technology has the apparent advantage of decreasing the overall cost of a project. To give you an idea, Jo *et al*. [11] did research on the possibility of using an intelligent reality system to aid aeroplane mechanic who are required to undertake difficult procedures as part of their job obligations. The goal of this system is to reduce the number of errors that occur during operations as well as the costs that are related to time by employing user friendly interfaces. Consequently, the VR system has been put through its paces in a variety of test hangars by stakeholders. Additionally, VR technologies have to be validated before they can be used in space. One useful illustration of this is the optical see through equipment installed in space stations, which can employ immersive VR as a pedagogical tool for the investigation of aircraft accidents.

This research examines how VR can be used to aid in the investigation of air crash accidents and to facilitate learning. Understanding how to improve training in air crash investigation through the use of VR features and steps is at the heart of this notion. One explanation for this is that it has brought a new level of understanding within our grasp. For example, a crash scene's force time history and contact with a target can be used to analyse the impact. Using a VR environment to teach this type of event can help students better comprehend it. In this study, the primary elements required in VR for teaching and learning about air collision accident investigation were identified as feature of surrounding region of the crash/accident, wreckage distribution, wreckage above the ground, wreckage in motion, and wreckage at the ground. Investment in air crash safety and business sense will triumph if this method is used. Investigations into plane crashes can be made better with the help of state based accident concepts. All present and anticipated accident investigation methods are covered. This is the paper's most important contribution.

2. RELATED WORK

It has been the responsibility of the aerospace safety and investigation centre to conduct the study dubbed air crash investigation. Delivery is done through given class, fieldwork, and labs, in the same way it has been done in traditional schools. Research into air crash investigations has both successful and problematic, according to past studies, Burgess & Moran [12] for example, focus on virtual environments for simulation of accident investigation. Learning methods are always changing in today's environment. Training and teaching in air crash accident investigation would be conducted in a digital laboratory environment. This study's major goal and criterion is to evaluate the effectiveness of a post crash investigative team. In this study, the effectiveness of using virtual laboratory environments in accident investigations is evaluated and

the advantages of these environments are outlined. There is a clear need for the air crash investigation educational system to integrate virtual learning as an integral part of the investigation process. Concerns about the approach of planes in frequent communication are discussed by Hecht [13].

One of the most critical conditions for a successful air accident investigation to have the public's and the aviation industry's confidence that an independent and objective investigation can be conducted by the agency. Quite a numenbr of reserch within the contex of this area comes with relativel the same finding [14]. An analysis of the accident investigation agency's actual and perceived independence. The use task analysis and a competency framework for air accident investigators to illustrate the hierarchical nature of task assignments. Why do aviation accident investigators do what they do? That was the focus of this study. Air accident investigators need an to structure and organise the many tasks they must do. To validate hierarchical task analysis, the panel of subject matter experts should be used, and each panel member should elicit their own competences. Another key impediment to the air crash investigation is the difficulty of adequately documenting the causes of true professional accidents and the nuances involved. While conducting research, a competency framework was built and is planned to be used in the selection and training of future investigators from a number of safety critical domains. It will also provide a detailed guide to show whether people are good investigators and those who aren't. Some extremely important cases have shown that determining the incident's learning value before gathering evidence can be a difficult and time consuming endeavour. In order to look into specific types of incidents, it has been noticed that investigating agencies make an attempt to participate in some measure. Researchers have shown that investigators work best when they are in a neutral environment, free from bias toward their own ideas or preconceived notions, and free to gather the most relevant information available at the time. As it turns out, this is the case. This matter must be left up to debate about the real causes of the incidents. In addition, a peer review should be requested proactively. In order to operate effectively in multidisciplinary teams, it is vital that each team has a different approach to the subject at hand and a different expert perspective.

There are many ways to used data for analysis for determing how data can be manged when it comes to air crash investigation with VR [15] used the European statistics on accidents at Work protocol to study the effect of accident investigation reports on their causes. The analysis of the immediate causes is a strategy used to identify potentially hazardous actions and circumstances. There's a plan in motion here. There follows an in depth investigation into the actual cause, and then you determine the total events that are being examined. In addition to the active faults, latent faults, and management system problems that have been discussed in greater detail, this is also mentioned [16]. A report should be able to access databases that produce reports on accidents investigated, with the purpose of lowering the amount of errors and omissions in that report. Prior empirical research on learning air crash investigation, despite its lack of focus on VR/AR, found that the vast majority of past studies linked to this topic showed substantial results.

When it comes to air disasters, an excellent example of a work focusing on how an accident occurs, as well as how it affects the environment and people. Flight incidents are described in detail in the report, which also identifies cause factors that contributed to them and analyses what measures might be taken in future cases to prevent them from happening again. It was found that the US army's accident investigation approach is the most extensively used technique in the field of accident investigation. Why did this happen? What causes this to happen? What can we do to prevent this from happening again? This is the plan that will be implemented. When it comes to air disasters, the 3W employs a four step process to determine if or not human error was to blame [17]. Organization and preliminary examination, as well as the collection of data and analysis of data. Completion of the technical report phase it is customary to begin the inquiry by assembling the investigative team and providing them with background information on the investigation and the occurrence in issue. Next, this team will travel to the scene of the accident for a first inspection. Data collection includes actively gathering the human cues, physical material, and environmental attributes that are linked to the occurrences. The information gathered during the data collection stage is examined using descriptive statistics, and the results are analysed throughout the study's analysis phases. 20 diagnostic errors and 37 action errors, according to the data, were observed in the system. Ultimately, a technical report outlines the evaluation's findings and conclusions. Errors seen are an important attribute toward understanding the cause of air crash mishaps, as this work relates to the approach given in the current study [18].

One of the promising technological impact of 2021 is VR, a lot of institution are adopting the use of VR for various task. Previous empirical research studies on VR for air crash investigation learning [19]–[24] do not highlighted the important of efficiency and usability of VR, treatment of flaws and omission of information, keeping the VR interaction simple and easy, and the impact of VR immersion, but mostly focus on investigating design and development, typical to this, is the work of Anniballe *et al*. [6], which design and developed an AR for air crash investigation in order to recreate a real aircraft crash scene. This was done through the assembling of the wreckage distribution and the features of the surroundings areas. Hence the development was performed by the acquisition of 3D scans of both the crash site and the wreckage, with

elaboration of scans to create a digital model of the crash site, and finally, the implementation of the AR experience to be viewed with an AR device. The contribution of the study shows that AR can support effectively air crash investigators and trainees as a useful element of virtual lab. The research further described that AR was adopted in aviation, but only related to support and maintenance, hence it was not on air crash investigation, similarly, in the field of air accident investigations, it has been revealed that there is no specific VR/AR application implemented as of year 2020, even though some implementations of VR on car crash investigations were proposed, but it was still held that AR has been found as a learning resource in air crash investigation training courses, as well as in aeronautics, however, the aeronautics uses virtual lab environment which is not a VR/AR [19].

3. METHODOLOGY

This study focuses on the conceptualization of fundamental elements of VR that are essential for the teaching and learning of air crash event investigations. These components are essential for the instruction and education of students interested in air crash event investigations. Following the introduction to the methodology, the study approach centres its attention primarily on the conceptualization of the features that ought to be made accessible within the VR. Figure 1 illustrates the conceptual model that was proposed in the paper, while Figure 2 illustrates the design for the development of VR that is associated with this area of study. Both of these figures can be found in the same document. The dimension which this research proposed to be the features required for VR that will be used for learning air crash investigation are as follows: feature of the surrounding area of the crash or accident, wreckage distribution, wreckage above the ground, wreckage in motion, wreckage at the ground, spatial view effect, and full view projection.

3.1. Conceptualization

The conceptualization of this study is centred on the development of fundamental elements of VR that are essential for the teaching and learning of air crash event investigations. This study's target component is presented in Section 3. In most cases, one can extrapolate the interactions of the proposed VR features by using a view that is simplified at the scene of the aeroplane crash and that are presumed to be of interest. The dimension feature of the surrounding area of the crash or accident, is conceptualized in this research, to reflect the surrounding area of the air crash or accident is operationally defined as the appearance of the surrounding air crash site in the VR. If there are any casualties as a result of the aeroplane crash, the immediate environment is likely to be the most traumatic and destructive experience a human body can go through. This, of course, depends on the specifics of the accident. In order for the investigation team to gain a deeper understanding of the situation, they must visualise the disturbing VR scenes that involve dead people.

Wreckage distribution can be operationally defined as the density of wreckage above the ground, wreckage in motion, and wreckage at the ground in an air crash accident scene that is shown with interactive highlighting techniques in VR. The presentation of a crash site is typically required for this, and in many instances, there will not be a single piece of the aircraft that cannot be removed by two people; the engine is the only exception to this rule. In most cases, the pieces will be no larger than what a person's hand can comfortably hold. When one considers that the human body is significantly less resilient than the aeroplane itself, it is possible to picture the conditions in which those who perished in the accident found themselves. However, their physical state and appearance may be different, which is something a learner needs to be aware of. That is to say, even though the wreckage is still in the air, its state and status, which are both susceptible to distribution, may not be the same when it is in motion or when it finally reaches the surface of the ground. Therefore, in order to facilitate a deeper level of comprehension, it will be essential to present these discrete phases in VR in an enhanced flow. The importance of this kind of problem was brought to light in a number of earlier studies [20]. Therefore, in order to facilitate a deeper level of comprehension, it will be essential to present these discrete phases in VR in an enhanced flow. The importance of this kind of problem was brought to light in a number of earlier studies [20]. Many studies also provide some interesting approach, such as modeling that is linked with positioning analysis inside 3D visualisation is also very important [25]. In addition, torque ripple minimization was proposed in Aihsan *et al.* [26], and impedance characteristics in the visualisation of spatial movements were also reported in Choudhury *et al.* [27]. The Real time visualisation connected with the modified programmable universal machine was also highlighted by other studies [28], [29]. Another example of the application of visualisation may be seen in the interpretation of sign language through the use of hand movements [30]. In a similar vein, Chae *et al.* [31] proposed a VR based hand gesture identification system that used a density based CNN. The visualisation connected with trajectory reconstruction has been demonstrated in Amar *et al.* [32], and lastly, nature grasping has been revealed in Tian *et al.* [33].

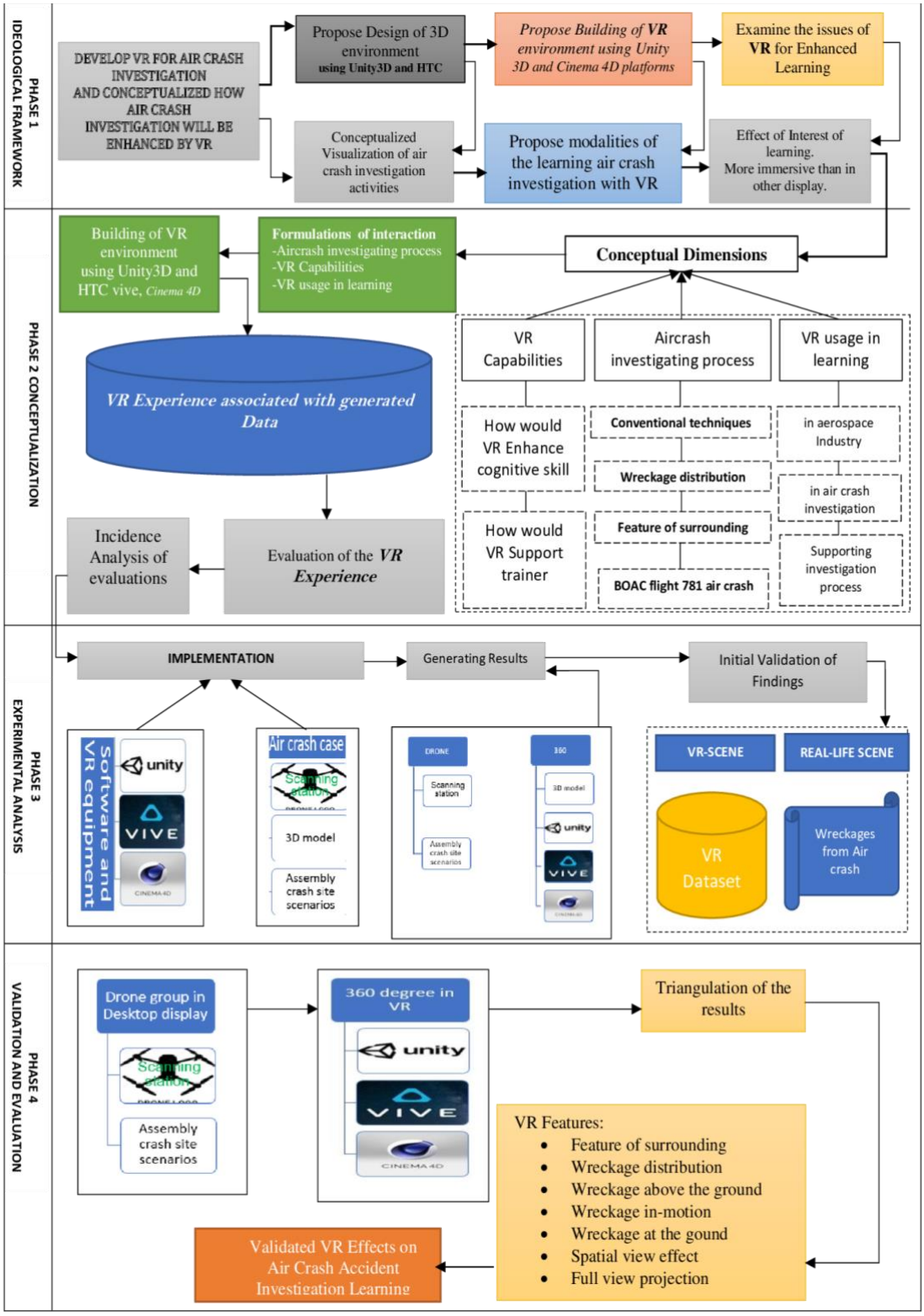

Figure 1. The proposed conceptual framework

The spatial view effect and the full view projection in VR, both of which are important components of this current study, are essential for the teaching and learning of air crash event investigations. Because they will give the illusion of how to present layer by layer and step by step details of the air crash investigation scheme for learning, these features are required because they are necessary. As a consequence

of this, the current study has it with due consideration on the job of marking the position of every piece of what had been a human being, from any angle, and having them from different resolutions had to be very difficult for everyone who was involved. Learners will be better able to comprehend more information if it is presented to them in a VR setting. With this features conceptualized they can be used for the design of VR.

3.2. Design process of VR for air crash investigation learning

The design of the VR environment needs to take into account the learning steps at an appropriate level in order to achieve the desired pedagogical result that can be achieved through the utilisation of the VR environment. In light of this, it is recommended that a design science research methodological approach be utilised during the process of designing the VR environment for the purpose of gaining knowledge regarding air crash investigation. In order to make full use of the potential offered by the newly developed VR environment, this will be carried out as shown in Figure 2. In the figure, the first section dwells on the system requirement, and design followed by the learning modalities events and finally the implementation. It is necessary to collect data or conceptualise the system components in order to carry out the system analysis and design, just as it was done in this current research in Section 3.1. This was also done in the previous section. This was done in order to make room for the analysis and design work that needs to be done. After all of the requirements have been compiled, the next step is to develop a basic prototype of the product. Alongside the development of the first level prototype, it is strongly suggested that a user experimental study be carried out. These user experimental studies need to be conducted on two different groups of users in order to be valid.

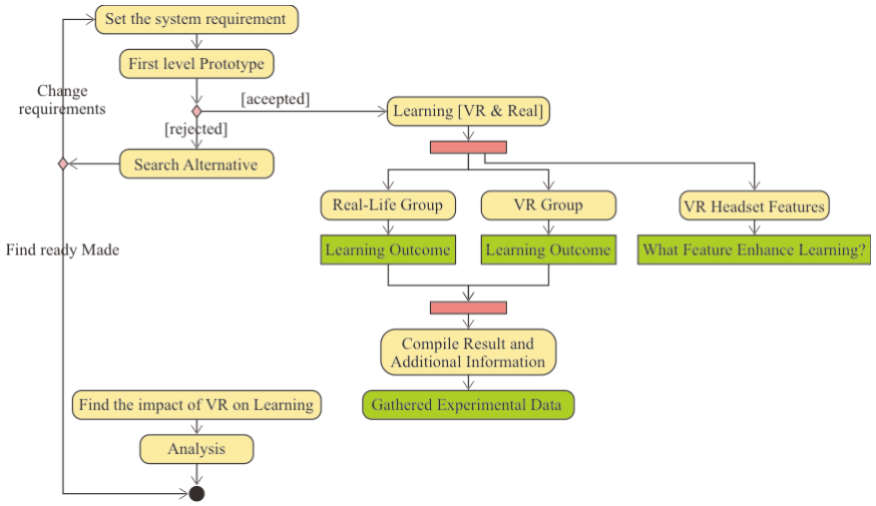

Figure 2. The design and development stages involve for VR

In the user experimental study, the participants ought to be split up into two groups—call let's them group A and group B—prior to the actual experiment. In contrast, individuals in group A will be given instructions on how to use the VR headgear and the participants in group B will be given a safety briefing. Participants in group B will be given the experimental criteria that are directly linked to the learning outcomes for the tasks, and they will be instructed to process the accident scene of the aeroplane crash. These experimental criteria will be directly linked to the learning outcomes for the tasks. In a manner analogous to this, the participants in group A will carry out the examinations utilising the criteria that are similarly and directly related to the learning outcomes associated with the various tasks: the activities that they carried out in order to process the site of the plane crash in order to arrive at the educational outcomes necessary for fully comprehending the scene which characteristics did they find in order to fulfil the learning outcomes for investigation performance? In order for them to arrive at the learning outcomes in relation to the data that was discovered during the investigation of the aeroplane accident, what do they believe to have taken place in order for them to arrive at those out comes?.

Triangulating the findings at each step allows the researchers to validate the conceptual framework, the design and development approach that was proposed, and the user experimental study that was necessary for this study. This will assist in gaining a more in depth comprehension of the numerous applications that VR has to offer in the arena of aviation accident investigation. The most crucial step in this process takes

place before the actual implementation and involves conducting research on the end users. That is to say, there is a requirement for appropriate testing to be carried out in order to determine how well students will comprehend the application of VR and the experiences that they have had. As a consequence of this, the fundamental elements of VR that were suggested in this study will be achieved, as well as the requirement for them in order to have an effective learning modality of air crash event investigations.

4. DISCUSSION

This study focuses on the conceptualization of fundamental elements of VR that are essential for the teaching and learning of air crash event investigations. These elements are essential for the teaching and learning of air crash event investigations. Students who are interested in learning about air crash event investigations absolutely need to have these components as part of their educational experience. The concepts are only meant to be associated with the actions or formal steps required for learning that is necessary for air crash investigation. The methodology for the research focuses its attention primarily on the conceptualization of the features that should be made available within the VR. Although it is necessary to proceed through a series of stages for the development of the concept before validating the concept, the study highlighted those important components that were associated with each stage. The conceptual model that was proposed in the paper is also associated with the design for the development of VR that is associated with this area of study.

The study places a great deal of significance on both the structure and the idea that underlies it. Despite the fact that the design is generic, the concept is primarily associated with the learning of air crash accident investigation. As a result, the current research has proposed the most primary features of VR that are necessary for learning and teaching about air crash accident investigations.

The following are the primary VR features that are required for teaching and learning about air crash accident investigations using VR: feature of the surrounding area of the crash or accident; wreckage distribution; wreckage above the ground; wreckage in motion; wreckage at the ground; spatial view effect; and full view projection. These features include: feature of the surrounding area of the crash or accident; wreckage distribution (VR).

The significance of the study lies in the fact that it is impossible to overstate the significance of VR without first having the opportunity to experience it for oneself. When utilising it as a tool for teaching and learning, one must keep in mind that it is also a process from which it may face challenges within the system of VR itself. This is something that must be kept in mind at all times. It is likely that this will be connected to the rendering and storage of the VR system bundle, both of which will unquestionably have an effect on interactive learning and study. In spite of the fact that this problem is associated with system resources, proper data flow management within the system will assist in helping to optimise the use of the system resources on which VR depends. However, in order to investigate the influence of light to heavy weight rendering on VR required for learning in a variety of scenarios, research is required. Despite the fact that this is not one of the problems that the focus of this research is on, it is still a cause for concern. It is necessary to conduct research on real time VR rendering and interaction in order to carry out an experimental learning session. Utilizing the most appropriate rendering and storing systems from the very beginning to the very end makes it possible to achieve interaction in VR that is suitable for learning. Nonetheless, the stages are of the utmost importance.

In conclusion, despite the fact that this research has brought to light the necessity of utilising VR features that are required for teaching and learning about air crash accident investigations, as well as the wreckage distribution above the ground and in motion as well as at the ground, and the spatial view effect for full view extend projection, other approaches for bringing other features into play are also critically important. The utilisation of an improved VR scene, regardless of the position taken by the user, is capable of producing scenes at a higher comprehensible level than any other visual medium. This fact can be used to justify the use of enhanced VR scenes. Also, if the infrastructure that supports VR were more adaptable and efficient, it might become more widespread in educational settings. VR stands for virtual reality.

5. CONCLUSION

This research presents a conceptualization of the implications VR could have on the investigation and interaction of learning. The core of the idea consists on determining which components and processes of VR are necessary in order to improve the learning experience of air crash investigation. This can be due to the fact that we now have a better grasp of something. Take, for instance, the impact analysis at an accident scene, which involves capturing the force time history and striking the target contact. Teaching about this kind of occurrence within a VR setting helps bring reality into focus, making it simpler for students to comprehend. This research has attributed feature of surrounding area of the crash/accident, wreckage

distribution, wreckage above the ground, wreckage in motion, wreckage at the ground, spatial view effect, and full view projection as the main features required in the VR for teaching and learning of air crash accident investigation. Wreckage distribution is another one of the main features. Taking this course of action will result in reasonable investments in aircraft crash safety as well as sound business logic. Air crash investigations can be made more accurate by utilising state based accident principles that are both practical and successful. This approach takes into account both the existing and the anticipated methods of accident investigation. This is the most important point that this paper brings forth.

REFERENCES

[1] F. P. Brooks, "What's real about virtual reality?," *IEEE Computer Graphics and Applications*, vol. 19, no. 6, pp. 16–27, 1999, doi: 10.1109/38.799723.

[2] R. Villena-Taranilla, S. Tirado-Olivares, R. Cózar-Gutiérrez, and J. A. González-Calero, "Effects of virtual reality on learning outcomes in K-6 education: a meta-analysis," *Educational Research Review*, vol. 35, p. 100434, Feb. 2022, doi: 10.1016/j.edurev.2022.100434.

[3] M. A. Frigo, and Ethel C. C. da Silva, and G. F. Barbosa, "Augmented reality in aerospace manufacturing: a review," *Journal of Industrial and Intelligent Information*, vol. 4, no. 2, pp. 125–130, 2016, doi: 10.18178/jiii.4.2.125-130.

[4] B. Schiavi, V. Havard, K. Beddiar, and D. Baudry, "BIM data flow architecture with AR/VR technologies: use cases in architecture, engineering and construction," *Automation in Construction*, vol. 134, p. 104054, Feb. 2022, doi: 10.1016/j.autcon.2021.104054.

[5] M. Akbari, N. Ha, and S. Kok, "A systematic review of AR/VR in operations and supply chain management: maturity, current trends and future directions," *Journal of Global Operations and Strategic Sourcing*, vol. 15, no. 4, pp. 534–565, Jan. 2022, doi: 10.1108/jgoss-09-2021-0078.

[6] A. D\textquotesingleAnniballe, J. Silva, P. Marzocca, and A. Ceruti, "The role of augmented reality in air accident investigation and practitioner training," *Reliability Engineering & System Safety*, vol. 204, p. 107149, Dec. 2020, doi: 10.1016/j.ress.2020.107149.

[7] F. Salguero-Caparros, M. Suarez-Cebador, and J. C. Rubio-Romero, "Analysis of investigation reports on occupational accidents," *Safety Science*, vol. 72, pp. 329–336, Feb. 2015, doi: 10.1016/j.ssci.2014.10.005.

[8] X. Fan, X. Jiang, and N. Deng, "Immersive technology: a meta analysis of augmented/virtual reality applications and their impact on tourism experience," *Tourism Management*, vol. 91, p. 104534, Aug. 2022, doi: 10.1016/j.tourman.2022.104534.

[9] M. Choi, S. Ahn, and J. Seo, "VR-based investigation of forklift operator situation awareness for preventing collision accidents," *Accident Analysis & Prevention*, vol. 136, p. 105404, Mar. 2020, doi: 10.1016/j.aap.2019.105404.

[10] A. Lele, "Virtual reality and its military utility," *Journal of Ambient Intelligence and Humanized Computing*, vol. 4, no. 1, pp. 17–26, May 2011, doi: 10.1007/s12652-011-0052-4.

[11] G.-S. Jo *et al.*, "A unified framework for aug-mented reality and knowledge-based systems in maintaining aircraft," *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 28, no. 2, pp. 2990–2997, Jul. 2014, doi: 10.1609/aaai.v28i2.19023.

[12] S. Burgess and K. Moran, "Use of virtual environments for simulation of accident investigation," 2015.

[13] J. Hecht, "Optical dreams, virtual reality," *Optics and Photonics News*, vol. 27, no. 6, pp. 24–31, Jun. 2016, doi: 10.1364/opn.27.6.000024.

[14] T. Morimoto *et al.*, "XR (extended reality: virtual reality, augmented reality, mixed reality) technology in spine medicine: status quo and quo vadis," *Journal of Clinical Medicine*, vol. 11, no. 2, p. 470, Jan. 2022, doi: 10.3390/jcm11020470.

[15] E. Dincelli and A. Yayla, "Immersive virtual reality in the age of the metaverse: a hybrid-narrative review based on the technology affordance perspective," *The Journal of Strategic Information Systems*, vol. 31, no. 2, p. 101717, Jun. 2022, doi: 10.1016/j.jsis.2022.101717.

[16] R. Mishra, M. D. K. Narayanan, G. E. Umana, N. Montemurro, B. Chaurasia, and H. Deora, "Virtual reality in Neurosurgery: beyond Neurosurgical planning," *International Journal of Environmental Research and Public Health*, vol. 19, no. 3, p. 1719, Feb. 2022, doi: 10.3390/ijerph19031719.

[17] M. Newman, B. Gatersleben, K. J. Wyles, and E. Ratcliffe, "The use of virtual reality in environment experiences and the importance of realism," *Journal of Environmental Psychology*, vol. 79, p. 101733, Feb. 2022, doi: 10.1016/j.jenvp.2021.101733.

[18] R. V. Taranilla, R. Cózar-Gutiérrez, J. A. González-Calero, and I. L. Cirugeda, "Strolling through a city of the Roman Empire: an analysis of the potential of virtual reality to teach history in primary education," *Interactive Learning Environments*, vol. 30, no. 4, pp. 608–618, Oct. 2019, doi: 10.1080/10494820.2019.1674886.

[19] A. Christopoulos, S. Mystakidis, E. Cachafeiro, and M.-J. Laakso, "Escaping the cell: virtual reality escape rooms in biology education," *Behaviour & Information Technology*, pp. 1–18, May 2022, doi: 10.1080/0144929x.2022.2079560.

[20] G. Milosovski, C. Bil, and P. Simon, "Improvement of aircraft accident investigation through expert systems," *Journal of Aircraft*, vol. 46, no. 1, pp. 10–24, Jan. 2009, doi: 10.2514/1.38605.

[21] W.-J. Tseng *et al.*, "The dark side of perceptual manipulations in virtual reality," in *CHI Conference on Human Factors in Computing Systems*, Apr. 2022, pp. 1–15, doi: 10.1145/3491102.3517728.

[22] K. Tang, K. Gerling, and L. Geurts, "Virtual feed: design and evaluation of a virtual reality simulation addressing the lived experience of breastfeeding," Apr. 2022, doi: 10.1145/3491102.3517620.

[23] T. Hilken, M. Chylinski, D. I. Keeling, J. Heller, K. Ruyter, and D. Mahr, "How to strategically choose or combine augmented and virtual reality for improved online experiential retailing," *Psychology & Marketing*, vol. 39, no. 3, pp. 495–507, Oct. 2021, doi: 10.1002/mar.21600.

[24] N. Harz, S. Hohenberg, and C. Homburg, "Virtual reality in new product development: insights from prelaunch sales forecasting for durables," *Journal of Marketing*, vol. 86, no. 3, pp. 157–179, Jul. 2021, doi: 10.1177/00222429211014902.

[25] N. S. E. Budin and K. Osman, "Modelling and proportional-integral-derivative controller design for position analysis of the 3-degree of freedom," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 27, no. 1, pp. 62–70, Jul. 2022, doi: 10.11591/ijeecs.v27.i1.pp62-70.

[26] M. Z. Aihsan, A. Jidin, A. Alias, S. A. A. Tarusan, Z. M. Tahir, and T. Sutikno, "Torque ripple minimization in direct torque control at low-speed operation using alternate switching technique," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 631–642, Mar. 2022, doi: 10.11591/ijpeds.v13.i1.pp631-642.

[27] T. T. Choudhury, M. M. Rahman, M. R. Khan, F. Rashid, and M. R. I. Sarker, "Mapping of human arm impedance characteristics

in spatial movements," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 1, pp. 498–509, Feb. 2022, doi: 10.11591/eei.v11i1.3461.
[28] Y. I. Al Mashhadany and W. M. Jasim, "Real time modified programmable universal machine for assembly (PUMA) 560 with intelligent controller," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 20, no. 3, p. 1194, Dec. 2020, doi: 10.11591/ijeecs.v20.i3.pp1194-1202.
[29] Y. I. Al Mashhadany, "Virtual reality trajectory of modified PUMA 560 by hybrid intelligent controller," *Bulletin of Electrical Engineering and Informatics*, vol. 9, no. 6, pp. 2261–2269, Dec. 2020, doi: 10.11591/eei.v9i6.2579.
[30] M. I. Rusydi, S. Syafii, R. Hadelina, E. Kimin, A. W. Setiawan, and A. Rusydi, "Recognition of sign language hand gestures using leap motion sensor based on threshold and ANN models," *Bulletin of Electrical Engineering and Informatics*, vol. 9, no. 2, pp. 473–483, Apr. 2020, doi: 10.11591/eei.v9i2.1194.
[31] L. Liliana, J.-H. Chae, J.-J. Lee, and B.-G. Lee, "A robust method for VR-based hand gesture recognition using density-based CNN," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 2, p. 761, Apr. 2020, oi: 10.12928/telkomnika.v18i2.14747.
[32] R. H. E. Amar, L. Benchikh, H. Dermeche, O. Bachir, and Z. Ahmed-Foitih, "Trajectory reconstruction for robot programming by demonstration," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 3, pp. 3066–3073, Jun. 2020, doi: 10.11591/ijece.v10i3.pp3066-3073.
[33] L. Tian, N. M. Thalman, D. Thalmann, and J. Zheng, "Nature grasping by a cable-driven under-actuated anthropomorphic robotic hand," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 17, no. 1, pp. 1–7, Feb. 2019, doi: 10.12928/telkomnika.v17i1.11006.

BIOGRAPHIES OF AUTHOR

Faisal Othman H Alburaidi is currently a PhD student at the Centre for Computational Engineering Science, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, UK. His research interest lies within the field of Virtu-al reality and augmented reality for enhanced technology learning. Knowledge in improving the usability of websites. Experience in C and C++ programming. Experience in E-learning contents. As a result, he dwells on his area of Virtual Reality/Aug-mented Reality for enhanced technology learning in computational science for aero-space applications. He can be contacted at email: faisalb21@hotmail.com

Karl Jenkins is currently a PhD student at the Centre for Computational Engineering Science, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, UK. His research interest lies within the field of Virtu-al reality and augmented reality for enhanced technology learning. Knowledge in improving the usability of websites. Experience in C and C++ programming. Experience in E-learning contents. As a result, he dwells on his area of Virtual Reality/Aug-mented Reality for enhanced technology learning in computational science for aero-space applications.

Tom-Robin Teschner is currently a PhD student at the Centre for Computational Engineering Science, School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, UK. His research interest lies within the field of Virtu-al reality and augmented reality for enhanced technology learning. Knowledge in improving the usability of websites. Experience in C and C++ programming. Experience in E-learning contents. As a result, he dwells on his area of Virtual Reality/Aug-mented Reality for enhanced technology learning in computational science for aero-space applications.