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Users Experience with VR System: Current State and Development Directions

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Abstract

Virtual Reality (VR) system is at its maturity to practice within many fields of studies. It is already recognized internationally and it's a reliable system to achieve user sense of presence and level of engagement among the users. However, the system still needs further advancement, as there are still numbers of concerns within the system itself that can demote user experience value. This paper attempted to classify the presented studies by researchers from articles sightings between years of 2007 to 2017 into three main components namely the technologies application platform, design of the application systems and construction of virtual environment (VE) for the application system. Then the review of design and development issues that concerns on users experience within the area of VE exploration and creation are also included. The filtration of selection papers is not discussed here, and in this review process, there is no empirical assessment. The objective of this paper is to point out and learn about the current state of VR and the issues faced in order to further promote the connection between user experiences with the system itself. Moreover, it is to level up the acceptance practices among users and continues publicizing the benefits of this complex system in various fields of use. Finally, with the review findings, this paper recommended VR trends for future research, design and development directions.

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1. Introduction

VR is defined as a system application that is delivered through 3-dimension computer imageries in simulated environment. It offers users with the possibility to immersively explore and experience using specific designed electronic technologies for visualization and/or to perform real-time interactions within the created VE or virtual world [12]. VR has the capacity to provide the real world with virtual data and experience closely [13]. It is also found to be in practice in many divisions such as industrials, simulations, entertainment, VR centers and other more [30]. In addition, the system has the potential to bridge users' limitations on accessing and interacting in virtual locations with no concern for distance, time or danger [6]. According to [8], VR is in its trustworthy phase at this level and its use receives global recognition because of its inimitable design features. There is also a vast number of VR systems found applied to several study fields [12]. Conversely, due to several issues during the design and development phases the systems are still seldom used. The disadvantages can be derived from the application system's cost, complexity, accessibility and maintenability [24]. Although there are many previous studies, with the rapid advancement in technology, it is important and necessary to review the trends of this application system in the future. Selections of reviewed papers

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are in the range of publishing years 2007 to 2017. Nevertheless, this paper does not present the information on paper purification process and in this review process there is no empirical evaluation conducted. This paper only presents the studies by researchers focusing on VE exploration and development issues faced within the technologies platform, application structure and reconstruction of VE in VR as classified in Figure 1.0.

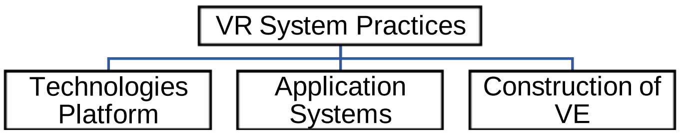

Fig 1.0: VR System Practices Classification Issues

In this case, the VR system involved creating a rich interactivity environment for users to explore and interact freely in a whole artificial built world [5]. Moreover, understanding and learning about the issues within the context can foster a closer connection between the system and the users in order to attain a high level of engagement and sense of presence when experiencing the system. User understanding in the design and development phase is more vital, rather than focusing heavily on the features of practice or invention only [24]. The concerns can be derived from implementation of both hardware and software within the system. As innovation of technologies is advancing, it reveals new constraints within the platforms though it can offer several new possibilities to users' experience [28]. On top of these, the technologies utilized can demonstrate variances in installation and setups of software and hardware to input and output to produce 3D imageries for exploration. For instance, head-mounted display (HMD), desktop, smartphone, websites and many more. Besides that, enhancing the immersion of exploration, the need to consider applicable design in the application systems plays a significant role to allow users to visualize the imageries, navigating from places to places in VE and good interaction techniques to interact with virtual objects within the virtual world. Apart from it, methods of constructing VE for VR application system involve several expertises in the field of study during the development phase [28]. It may draw a great deal of considerations and concerns to achieve its objectives.

2. Reviewed Issues

Studies in VR system show various issues to overcome as to further minimize the barrier of communication and extend the sense of realism between users with the system itself for exploration and VE development method. This section focuses on identifying the issues and classifying the studies of the researchers within the areas of technologies platform, application systems and construction of VE. The design and development of the VR system aims to enhance the immersion, engagement and sense of presence of users during the exploration.

2.1 Technologies Platform

VR system can involve in many platforms to output its application and contain both unique design and development of VR system hardware and software in order to provide users to experience wholly inside the constructed creation of VE. The listing of platform usage is gathered within articles sightings as illustrated in Figure 2.1.1.

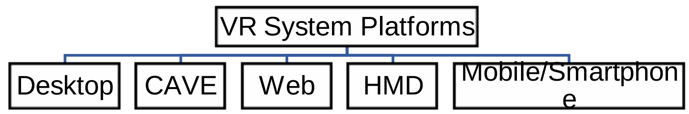

Fig 2.1.1: VR System Technologies Approach

Multiple installation ways of technologies application platform and different content design presentation in-system imbedded to VR system lead to different users' perception and experience [22]. First of all, on desktop innovation, it has been around for many years and it continued to evolve rapidly in terms of performance and ergonomic design to meet various users' expectation and acceptance. Desktop platform utilized in VR system is possible with various combinations of input and output of software to run VR application system and sensory hardware for users to interact within the system in order to enable users to explore and experience themselves inside the VE [27]. The advantage of familiarity of use of this technology along with the traditional hardware inputs (keyboard, mouse, joystick and etc.) is described in [27]. There are concerns highlighted among users, showing signs of physical discomfort depending on the presented setups. For instance, inappropriate lights and glares projection cause stress to users' eye or motion sickness that derive from low performance of the technology.

Next on CAVE system that is extended from desktop version usually requires bigger space for installation to allow freedom for users' movements to achieve higher sense of immersion and presence within the VE. Furthermore, it can be presented in various display output from single screen to multiple screen projections or non-stereoscopic view to stereoscopic view and various sensory tracking devices to capture users' input for interaction[11] [27]. The strength of this system can highly produce users sense of presence and immersion compared to any other systems, yet considerations sighted from several articles noted on the expensive cost of hardware needed, complexity in installation, high maintenance, large spaces required and the requirements to involve several systems development expertise.

User's accessibility to the content in VR system is also an issue highlighted whereby users require an easy access to the content via Internet [29]. Therefore, web application system platform can allow this possibility. In spite of the benefits, studies from articles named that the high dependencies to

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Internet connectivity may limit the accessibility among the users. The strength of connectivity also plays a part in system performance feedback that could result in delaying the rendered images and/or the interactivity that leads to demotion of user experience. Besides, most VR web system is restricted to run on selected hardware only. Likewise, though with advanced technology of Internet that allows easy access to the Internet, security issues are also another concern that could affect individual safety such as cyber-attack. Yet other considerations on interaction design should be well thought to serve different platforms that utilize web into VR system.

HMD is a wearable technology for monitoring and visualizing purposes which is placed on the user's head. It demonstrates the ability to achieve level of immersion due to the display structure that fully covers the users' perception. There are various designs of HMD applications that come in various types of constraints depending on the system design approach [27]. In conjunction to users' mobility, many studies showed that mobile or smartphone in VR system is frequently working together with specified design HMDs to meet flexibility in user movement while performing tasks inside VE. However, concerns in HMDs are focused on the discomforts in health and safety during user experience that can affect by many terms compared to other platforms depending on individuals' condition. It may derive either from the ergonomic design of the headset or the design of VE development. Moreover, mobile or smartphone unit must be able to support gyroscope and accelerometer for tracking user's movement to fully achieve the immersion.

2.2 Application Systems

There are several researchers discussed on different exploration design and development approaches within the use of VR system to enable users to engage and immerse inside VE. These studies are classified into applied visualization system, navigation system and interaction techniques that are put in practiced.

2.2.1 Visualization

There are various significant consideration factors to display immersive visuals. Table 2.2.1 reviews the visualization design approach imbedded with VR system in practice from the finding of articles.

Table 2.2.1: VR Visualization Approach

Author(s)	Visualization Device(s)
[22] [27]	CPU monitor or projection screen
[8] [11]	Tracking cameras with wearable technologies and stereo projection
[1] [15] [21] [22]	CPU cabled version or smartphone/mobile
[10]	Modified HMD

Central processing unit (CPU) monitor and projection screen are described in the studies that utilized the desktop display approach to output the immersive visuals to different resolutions of monitor screen (LCD or LED) or the standard projection screen from the projector in which the visualization is done using traditional hardware inputs [22][27]. Despite the benefit of a high-performance operating system, mobility lack of realism and noticeable motion sickness among certain users present the weaknesses.

[11]Applied VR CAVE system installation design approach consisting of a stereo projection to project the immersive virtual environment on four various surfaces together with an infrared cameras system installed to monitor user interaction through wearable stereo glass. The four images that are projected are shown on the floor and others on the wall as shown in Figure 2.2.2. To stimulate the virtual environment, each surface display includes a unit of high specs CPU with graphic card. However, this approach probably results in the limitation of movement and manipulation of virtual objects within VE due to the specified spaces and lacks precision in capturing user input. Apart from that, the large panoramic stereo curved screen was used in another system for immersive visual projection. Although these system setups can deliver great level of immersion and engagement among the users compared to any other system, it can be costly and complex depending on the design specifications to run the system that can lead to limited immersive features implementation [8].

Figure 2.2.2: VR CAVE Visualization System Installation [11].

HMDs in present studies come in range of devices and setups conditions. Visuals that are projected on HMDs both cabled and mobile VR versions are fixed with two unique design lenses mounted in glass-like device to achieve stereoscopic vision [27]. In addition, HMDs can now be generally obtained at an affordable price compared to earlier years [1]. Within the system, however, there are still drawbacks that can influence user experience outcomes. Due to the visualization features provided by HMDs, the main problem is that users that experience movement sickness that causes nausea particularly with devices that operate at lower performance [15][21]. Additionally, graphic pixilation is apparent, and this is due to the graphics optimization need to reduce visual rendering in real-time without delay [15].

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Visual synchronization is also a problem when the device is shared between users during use, whereby the device fixes the 'front' sight when the application system begins and other users continue using the device standing at various rotations, experiencing the 'rear' sight. In order to continue the exploration, users can experience confusion and need wide body rotation to find the right sights to perform the required interaction in the VE [21]. Identically, cabled version of HMD that performs at higher performance compared to mobile HMD demonstrated disscomfortness and distraction when user is perceiving the real-time 3D imageries with body parts movements due to the wires that are fixed in between the space of user movements [22].

[10] A modified HMD system was designed and applied which allowed users to experience either the virtual or the reality environment during exploration. The modified device is called Mirror Shade platform as described to be revised into a parallel reality system. Use of this HMD is installed indoors with monitoring system to support the alternative approach to visualization. One of the problems highlighted is the feeling of discomfort in keeping a number of devices on hand during the actual visit to the exploration. Besides that, the visual rendering accuracy is not proportional to the actual environment, and the user position update tends to be delayed during movement [10]. Maybe in the future with device advancement can improve on this issue. It seems to suggest that various visualization approaches raise different issues which affect the user experience during exploration activities. When choosing the right application system, focus in the design and development phases should be emphasized on the project purpose.

2.2.2 Navigation

In meeting the high level of immersion during the interaction of users, the goal of the VR navigation system is to achieve closely natural and free movement similar to the real world during visits to developed VE sites. Meeting this goal can be very dependent on the input and output of the application system in system design. In addition, the system requires the basic of designed 3D VE, controller device for users to input, monitor and visualize devices until users can navigate inside [19]. However, there are still gaps in distance for future improvement in order to attain physical acceptance similar to the navigation on the touch screen.

Table 2.2.2: VR Navigation Approach

Author(s)	Approach	Devices
[19]	Off shelves HMD with depth sensors	Kinect, Oculus Rift and Google Cardboard
[17]	3D user interface (Focus Sliding Surface (FOX))	Holographic screen projectors, Intersense 3D mouse and Kinect
[3]	User interfaces: i) focus-plus-context visualization, ii) touch-based camera, iii) continuous feedback	Stereoscopic projector, polarized glass and 15-inch touch screen
[25]	X3D environment with multimodal interface (XHTML and voice)	CPU traditional hardware

The problem listed is space, feedback from data, input recognition and voice dialog from articles sightings inside Table 2.2.2. Firstly, space issues from [19] research noted the safety restriction and restricted area for movement performance. Likewise, during the exploration activity only one user is allowed to be in the area of the application system. The authors also stressed the discomfort of the early version of cabled HMD, which suggests consideration of proper installation or advancement of HMD to achieve mobility. On the other hand, efficient system feedback is necessary if user input is to communicate the output. [17] reported on input method in accuracy that may cause delay or error feedback that contributes to unpleasant user experience while exploring in VE, unless users are already expert in input performance. Next, the input recognition for navigation deriving from monitoring body part movements demonstrates significant concern on the method of free space interaction. Application system with the present touch method does not operate in 3D space and the complexity of communicating is addressed in [3] to navigate in free space monitored by sensory tool. This is probably due to the unfamiliarity of mid-air movements. In addition to the above method, there are studies that intergrate voice dialog as a form of user-to-user communication between system.In line with the analysis [25] the authors suggested further allowing voice command as a form of navigation input. While using voice command may level the sense of commitment, consideration should be given to the precise use of language and the context of user education. Lastly, without a good navigation system imbedded with the application, users could feel frustrated, resulting in loss of interest in continuing the exploration activity.

2.2.3 Interaction

Researchers' findings on interactivity studies usually use specific designed tracking technologies to track the movement of users and sometimes with physical hardware combos for interactivity within the built-in VE. In addition, users are required to perform certain design gestures which are formed in the application system specifically for specific tasks. Table 2.2.3 highlights system approaches to interaction applications that are retrieved from articles focusing on exploration of VE.

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Table 2.2.3: Interaction Application System Approach

Author(s)	Controller Approach	Tracking Device(s)
[9]	Two long tangible blocks	Oculus Rift head-mounted display (HMD) and Leap Motion
[2]	Upper body with both hands	OptiTrack
[7]	Laser pointer	Ceiling-mounted IR camera
[20]	Arm-based on skeleton recognition	Microsoft Kinect Sensor (1st Gen) Camera
[23]	Upper skeleton of user's body gestures	Microsoft Kinect
[16]	Hand gestures	Two Firewire cameras
[26]	Upper body posture on shapes and types	Microsoft Kinect
[14]	Entire hand model with complete fingers structure	Leap Motion
[18]	Mid-air gesture-based interface	Microsoft Kinect
[4]	Imitating natural hand gestures	Oculus Rift HMD and Leap Motion

Depending on the application system design applied in practice there are numerous issues noted. Although some application system used similar controller method or tracking devices, it can result in different issues and challenges depending on the aims of the implementation of the practice and movements. The challenge that was mentioned several times in all the papers reviewed deals with tracking technology and it was presented on the lack of accuracy when detecting user activity. Lack of precision during input user interaction can cause user experience interruption and results to decrease engagement and present meaning. In addition, Microsoft Kinect, which is capable of tracking the full body movement of the user, can only function efficiently indoors compared to spaces that are exposed to external light source. Besides that, monitoring the implementation of the device is a limitation on limited space to identify the input movements of the user. Nevertheless, due to the limitation of tracking space, an assistant is required to guide users when using the device. This is probably because of the system's lack of feedback approach. Nonetheless, most of the tracking devices are only meant for single users.

Notwithstanding technologies approaches to gesture design often give rise to several complications. The major complaint is about the tiredness of free space performing gestures. This is due to the unfamiliar movements taught to users in performing such tasks in VE. Likewise, gestures application is suggested to have major differences in motion to avoid conflicts in gesture recognition that are recorded in the system. Citing on the tasks to be performed in VE, when communicating with objects, gestures design application should be similar to real world practice. This is to prevent misperception, because some application system demands that users remember and execute too many movements to complete those tasks. In this case, real world-like natural movements will lower the level of cognitive learning and decrease the memory abilities. With the recent innovation, the gestures of recognition, standardizing and simplification could not be tracked by all kinds of devices but the gestures would increase the level of acceptance and familiarity among users. However, due to the height of the diverse individual, distance from the tracking system and movements input patterns, the system suggested improvising improved recognition intelligence. All tracking devices and gesture designs therefore play an equal role in creating a high level of user experience immersion.

2.3 Construction of VE

There are a number of tools that are put in practice by developers to wholly construct an immersive VE with interactivity features. All the tools required to build VE contents that involve 2D or 3D graphics, audios and programming for interactivity development [30]. With the needs of different development tools, it is necessary to draw in multiple specialists as well as engaging the end-users for improvement feedback and collaboration within all individuals to create a maximized usability and user experience. Besides, complexity in the development can lead to other different concerns depending on the resources that are provided to the individuals. For instance, [31] points out the concern on high consumption of time and human resources during the design and development phases. The severe time used in engaging the users in the design process is highlighted too. Similarly, concerns on time needed in development phase can also occur in rendering the final output of imageries especially on high-resolution 3D graphics production [32]. Even though graphic developers can produce high quality VE graphics, concerns are led in the lack of performance and responsiveness within the system that runs on insufficient installed hardware specification, particularly if it is to reduce graphic qualities to support large scale VE[33]. Further studies on VE construction for serious application explains on the lack of information accuracy are developed and presented to users can further lead to confusion and wrong knowledge interpretation. Moreover, research studies in engineering field still demonstrate gaps to achieve high quality graphics and performance within VR system to cope with different technology and application system design. Gaps can be derived from programmer and technology device engineers. Thus, it is substantial to involve huge amount of resources in terms of money, human resources, and high technology facilities and to develop and run a complex system.

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3. Recommendations

During the design and development phase attention should first emphasize the types of users and users history. Given the disability and knowledge the goal is to reach out to all audiences. Likewise, the technologies platform application that reflect different weaknesses with regards to the types of technologies utilized should also consider about the form of environment design and tasks to be performed by users to achieve the application output that is in line with the objectives with VR system implementation. In addition, design of technologies hardware should also count on ergonomic design to suit individuals' preferences as to maximize immersion without distraction that may results to discomfort factor and demote the level of user experience.

In addition, most reviewed papers recommended mobility graphical realism, efficiency, space for users to use, health factor, and comfort factor for future improvements while experiencing the system. For instance, movement mobility for disabled body parts audience may use their voice command or eye tracking to interact and navigate inside VE. Furthermore, designing a suitable user interface depending on the group of audience in performing certain tasks as to communicate and provide feedback to users input for better navigation in system. This can minimize the need of mentoring assistant. In terms of performance, we believe that with the advancement of technologies components development in future can overcome to support rich graphics quality and other VE assets element to further enhance users' immersion. On the other hand, on the limitation of space, there is already hardware designed developed such as 360^0treadmill machineries tracking system to allow users to perform free movement on the same spot. However, in the current state of time, the machineries are very costly for setups for individuals to experience. It also requires a lot of cables and devices attached to human-body parts for tracking and interaction to occur. Perhaps in future, this machineries cost is lowered and accessible for a greater pool of audience and not restricted to any fields of studies and individuals. In addition, as the VR system are known to produce motion sickness and though with the advancement of current higher performance technologies that has minimized this effect, it is still a taboo issue that occurring to the audience after a long run. Additional designs on flexibility function to customize the system elements such as head rotational speed or graphics quality and/or allowing different standing or seating position to suit individual preferences as to overcome the discomfort from cyber sickness and/or eye stress. Besides, gestures design for interaction should consider designing the motions performed by users are as similar to the real-world practice in order to enhance users' immersion rather than stressing the users to learn and remember the gestures. Moreover, suggestion to increase the accuracy for tracking and customizable users input within the system may overcome the exhaustion of executing gestures in free-space. Apart from all, there should be further promotion of tools for non-expert to output VE in VR system to reduce on the complexity and resources needs. It is already seen in market such as 3D scanner to capture real object and transfer into 3D graphics for application, yet it is still costly to capture and laborious processes in refining graphics for VE implementation. Additionally, most of the affordable machines have limited dimension and ability to capture small sized models. As for the interactivity and output of VE application system, they can be accomplished with more familiarized and user-friendly designed software engines that are usually used by many researchers or developers namely on game engines (Unity3D, Unreal Engines and etc.). While suggestions are made, more research on a suitable structure and testing needs to be carried out to decide whether the findings can further improvise the application system to meet the users' higher level of user experience during the VE exploration.

4. Conclusion

The main aim of this paper is to provide and insight of user experience with VR system that concerns within the classified area of studies focusing to achieve virtual exploration. Concerns are reviewed and reported under the classification of technologies platform, applications system and construction of VE to suggest on the future innovation directions. Nevertheless, this review process is not discussed on paper filtration and collection, and it does not provide any empirical assessment, but through understanding and learning from presented concerns it can assist researchers and even developers up front. Future work will perform to critically review and further justify on the evaluation of review in these research areas. This can certainly help in expanding other VR practice studies to reduce the complexity and to make it a multi-disciplinary research area.

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