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REVIEW OF VIRTUAL REALITY TRENDS (PREVIOUS, CURRENT, AND FUTURE DIRECTIONS), AND THEIR APPLICATIONS, TECHNOLOGIES AND TECHNICAL ISSUES

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ABSTRACT

Human-Computer Interaction (HCI) is concerned with how humans work with computers and how technologies can accommodate the needs of users to meet their goals. The early phases of Virtual Reality (VR) often involved head-mounted computers in which users immersed themselves, as they could act, perceive, and interact with a three-dimensional world. This paper has two objectives: to conduct a detailed review of VR trends (previous, current, and forthcoming) and to highlight the applications and obstacles that affect each trend. Reliable survey data was obtained from sources such as ISI, Scopus, Springer, IEEE, and Google Scholar, as well as websites. The main contributions of this work are: (1) analysis and summary of VR trends in the past, present, and future, (2) details of the technical limitations of each trend and explication of their applications, technological requirements, and currently available solutions, (3) illustration of the direction, developments, issues, and challenges for each trend (previous, current, and future), (4) identification of the direction and important trends that require more comprehensive studies by future researchers.

Keywords: human computer interaction, virtual reality, virtual environment, VR technologies, VR applications, augmented reality.

INTRODUCTION

Humans comprehend external reality by the five senses of hearing, vision, taste, touch, and smell. If one or more input from these senses is replaced by machine generated input, that person is, to some degree, in an artificial reality(Spear, Brian. 2002). Virtual Reality (VR) is an advanced system that allows users to be transported into a "virtual world". Users fully immerse in a VR experience via a combination of technologies, including a Head-Mounted Display (HMD), headphones with sound/music and noise reduction, a rumble pad, joystick, or other device for manipulation/navigation of the Virtual Environment (VE). These systems follow the user's head movements, giving the illusion of being surrounded by a virtual world (Li et al. 2011). In addition, VR can be defined as "A human-computer interface in which the computer creates a sensory-immersing environment that interactively responds to and is controlled by the behavior of the user" (Abdelhameed 2013). VR may also be defined as a technology environments in which users are immersed and may act, perceive, and interact with a three-dimensional world (Borsci, Lawson, and Broome 2015). A variety of VR systems have been developed and investigated, from low- to high- tech systems, including non-immersive 2D VR systems administered without helmets, to fully immersive VR systems with multimodal stimuli, resulting in mixed outcome efficacy (Li et al. 2011). Military and pilot virtual reality applications have achieved much success in training, showing these technologies have great potential (Djukic, Mandic, and Filipovic 2013). VR simulations have rapidly improved together with the requisite hardware and software systems(Djukic, Mandic, and Filipovic 2013). VR has recently been applied in several different areas, such as industrial simulations and cultural heritage documentation(Guidi etal. 2010). It has also been widely applied in the medicine, automotive, and aerospace industries, as well as education and entertainment(Häfner, Häfner, and Ovtcharova 2013). Most VR applications include a visual rendering component. However, efficient and relevant visual interfacing of a human user raises issues about visual interfaces and depth perception in computer generated images (Moreau 2013). Digital technology has come to dominate our daily lives and is bound to expand in the future, possibly in new forms of human-computer interaction (Peperkorn, Diemer, and Mühlberger 2015).

Jaron Lanier (1986) coined the term "Virtual Reality" to characterize a set of technologies that simulate a computer-generated 3D Virtual Environment (VE) that users would prefer to inhabit over a simple 2D display. Virtual environments immerse users by providing visual, auditory, tactile, and even olfactory sensory stimulation, using devices such as head-mounted displays and instrumented clothing (Galeazzi and di Milo 2011). VR is "a term that applies to computer- simulated environments that can replicate physical presence in places in the real world, as well as in imaginary worlds" (Alaraj, Tobin, and Birk 2013). Those familiar with the early phases of virtual reality often conjure images of head-mounted displays and data suits, but, more recently, virtual reality has been used to describe highly visual 3D environments developed with commercial game technology, such as the Unreal Engine from Epic Games (Alaraj, Tobin, and Birk 2013). Most VR technology face several constraints, including technical challenges and simulation sickness. These issues may be due to computer latency, which manifests in a poor simulation and a less than satisfactory end-user experience. Certain technologies include complicated head-mounted displays and input systems, such as

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specialized gloves and boots, which require special training to operate. Wearing these inputs can cause navigation of a "real" environment to become risky, due to the lack of "external" sensory information.

In this paper, we present a detailed review of VR trends (previous, current, and future directions), summarize them, define and explain the obstacles for each trend, and highlight their applications, technological requirements, and currently available solutions. We also illustrate the directions, developments, issues, and open challenges for each trend. In addition, we stress the need for further studies on important trends.

PREVIOUS WORKS

Numerous reviews have been published on VR trends. Spear's (2002) patent review explored the wide range of VR applications, the consequent increase in patent activity, and the corresponding patent trends (Spear 2002). Haklay (2002) completed a comprehensive literature and internet-based survey of VR and Geographic Information System (GIS)(VRGIS) applications, trends, and directions (Haklay 2002). Lin et al. (2008) surveyed VR software and technology in terms of four major trends: novel combinations of sensors for 3D input device design, bio signals (such as brain activity) as input mechanisms, haptic (touch) feedback through pseudo-haptic interfaces, and 3D UI's for multi-display interfaces(Lin, Otaduy, and Boulic 2008). Mahrer and Deffery (2009) reviewed VR for pain control (Mahrer NE 2009). Li et al. (2011) presented a comprehensive review of the literature. They explored clinical and experimental applications of VR for acute and chronic pain management, focusing on current trends and recent developments. They also proposed mechanistic theories, particularly VR distraction and neurobiological explanations, and concluded with new directions in VR research, implications, and clinical significance (Li et al. 2011).

The present work focuses on previous, current, and future VR trends, with a focus on applications, technologies, and technical issues, to give a unified view of VR trends as a future reference for a comprehensive study. Furthermore, the current work also focuses on applications which will require more comprehensive studies by future researchers.

SEARCH METHOD

Multiple sources were used to collect data for this paper. All synonyms of VR were identified and used as search terms for any related material published in the period 2010-2015. The main key words selected were "Virtual Reality" and "trends in Virtual Reality." Searches were conducted on reputable online databases, such as Web of Science (ISI), Science Direct (Scopus), IEEE-Explore (IEEE), Springer Link (Springer), and Google Scholar (Google). After applying filters, the search engines found five studies from ISI, 21 from Scopus, nine from IEEE, 17 from Springer, and 41 from Google.

VIRTUAL REALITY (VR)

In this section, we investigate the various uses of a VR environment. We explain the motivation to use VR before listing the applications, technological requirements, and currently available solutions (hardware and software) for VR environments. We also present the issues and open challenges of VR in terms of technology and systems.

Motivation to use VR

VR has recently been applied to training and education, where users can learn to operate complicated machines, such as airplanes; how to work in dangerous environments, such as burning buildings; in entertainment, such as videogames; and visualization, for instance, allowing users to "walk" through buildings that have yet to be built (Brooks Jr et al. 1992). However, most of these applications have been limited, as there has been little research devoted to the user interface and interaction techniques for immersive VR (Bowman and Bowman, 1999). In other words, they lack usability (Schuemie, 2003). VR is widely used in industries and is becoming more affordable for end users. At the same time, higher-education students want to be well-prepared for their professional lives and expect more courses with practical applications of theoretical knowledge. Moreover, they benefit greatly when given the possibility to improve their soft skills (Häfner, Häfner, and Ovtcharova, 2013).

Applications of virtual reality

Technology becomes successful when it capitalizes on growing demand. Without such growth, technology or products remain in a niche supported by a small number of high-end users (Tang, 2012). Below, we list common applications of VR.

Table-1. Applications of the virtual reality.

Application domains	Brief descriptions
Design Of Cities	• Provide detailed virtual cities in virtual reality environments • Time and resources are required for programmers and CAD modelers.
Rebirth Of Physical Urban Models	• Environmental Simulation Laboratory constructed a full-scale model of San Francisco by employing a video camera with a model scope fixed to a moving gantry. • This device is capable of simulating the sun and shade at various times of the year.
Architecture And The Art Of Image Making	• Allows Architect to direct measurement of scaled drawings by orthographic constructions that encompass plans, sections, and elevations of plan, section, elevation determined design solutions through achieve the architect's preference for working in plan and elevation that reflected by CAD applications. • Capable the architect to create his concept in the plan that occurred via Visualizing the design in perspective.
Work Environment And Architecture	• A team of professionals establishes a design and shares it in a versatile and flexible work space with a large number of documents, drawings, and CAD models.
Archaeology and VR	• Archaeologists capture data of historic sites and buildings using long and short-range scanners. • Scanner data may be used to reconstruct these sites in their entirety by reproducing missing elements. • A smog-free environment can be created in a virtual space.
Medicine	• Medical students can study human anatomy at any scale, whether tissues, cells, or organs. • Life processes may be understood in real-time using a virtual human, which simulates physiological processes of patients. • Artificial intelligence improvements, kinesthetic feedback, and user interfaces are available for neurosurgery, in which robots can assist in operations.
Games	• Games can attain a higher level of realism in simulating water, photo-realistic lighting, and shadows.
Military	• The demonstrated value of flight simulators can lead to other applications of VR training in the military, such as tank simulators. • Speech recognition technology, can give students feedback on appropriate responses with native speakers. In addition, this technology focuses on common responses and is useful for students that have limited prior experience in foreign language instruction.

VR had promising beginnings in urban planning, with several cities having used it for such applications, allowing planners to "drive" on roads, view existing cities, and propose developments. More recently, these models have been capable of simulating sun and shade at several times of the year. From the perspective of image making, architects have a new tool for design and construction management. However, Internet-based solutions currently have greater significance in architecture design than VR. Google recently supported a Virtual Rome project, which may be viewed on Google Earth. Virtual environment technologies have also greatly improved, becoming completely interactive, such as the "Lindsay Virtual Human," which uses advanced 3D imaging for medical applications. Graphics and computing power have also greatly improved for the use of VR in gaming applications. Finally, the ultimate VR challenge in military applications is to coordinate actual infantry in simulations of actual battles.

Open challenges in VR

Several challenges face VR including enabling technologies, systems engineering, and human factors. In spite of this, VR has passed the point of "almost works" to "barely works." The most crucial challenges are:

Table-2. Open challenges for the virtual reality.

Challenges	Descriptions
Technologically	• Gain an acceptance level with down latency • Attain greater than 1 M polygons in real-time by rendering massive models • Select a suitable display for each application. Examples include bench, panorama, and HMD. • Generate VR illusions by producing satisfactory haptic augmentation.
Systematically	• Effectively interacting with a virtual world encompasses: path finding, specifying travel, manipulation. • Efficiently modelling the world entails using image-based techniques and non-existent worlds through CAD byproducts.Measuring the illusion of presence and its operational effectiveness.

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The technology has several limitations. Tracking devices produce unnatural results, such as allowing the user to walk through walls. Another limitation is the lack of standardization within the medical field for hardware, protocols, and usability of VR technology. Users thus have difficulty navigating in 3D space or performing actions in free space.

VIRTUAL REALITY TRENDS

In this section, we reviews the previous, current, and future directions of VR trends. We first illustrate previous trends in industrial applications and highlight their issues and limitations. We then demonstrate 2015 trends in VR and Augmented Reality (AR). We then detail the future directions of VR.

Previous trends

Previous trends in real-world applications did not use head-mounted displays or gloves, but immersive or wall-based projection technologies and simple input devices.

Table-3. Previous trends of the virtual reality.

Technologies	Brief descriptions	Problems and limitations
HMD	Head Mounted Display (HMD), also known as Helmet Mounted Display (Saggio and Ferrari 2012). HMD is a visor worn on the head of the user with two or one optical displays for one or both eyes (Saggio and Ferrari 2012).	• Limited resolution. • Wires and cables limit human movement. • Difficult to engage with other users in the real world and ergonomic issues of wearing a helmet.
GLOVES	VR gloves gave the user the ability to touch and point, and measure attitude, movement, etc. of the hand/fingers continuously.	• Meantime between faults is low. • No custom sizes. • Complex- 30 values in 30 Hz, • Unnatural- no force feedback for the hand when touching something, • Lack of comfort and ease of use.

Recent experiments with a power wall at BMW for CAD evaluation of car shapes, from which the following results were obtained: 6D user interface is closer to reality. There is a great difference between laboratory trials and actual usage. Small differences in the user interface make a large difference for the user. Users should drive the process and iterations with the developer. Hence, the obstacles of the previous VR trends are user effect, interaction, users, and technology.

Current trends in virtual reality

Virtual reality and augmented reality trends

At present, businesses and consumers believe it imperative to see and experience things that cannot be physically present. Additionally, they believe to imagine layers of virtual data onto real-world environments, creating deeper and more significant experiences. Hence, technologies for VR and AR are used to solve these challenges and problems (5 top VR and AR trends. 2015). Table 4 shows the common technologies for trends in VR and AR, lists their applications, and highlights the advantages of their technologies and applications.

Table-4. Trends of the virtual reality in 2015.

Technologies	Applications	Descriptions	Advantages
Wearable Experiential Technology	Google Glass	Wearable AR and VR hardware technologies require better presentation for broader acceptance.	Affordable VR headsets will make VR mainstream.
Accessible Heads-Up Displays	Samsung Gear VR and Google Cardboard	Made VR hardware an affordable technology. A smartphone peripheral usable by anyone, rather than exclusive for gamers.	
The Land Rover Virtual Showroom	AZEK 3D visualizer (Daqri Smart Helmet)	• Merge AR and VR for business and marketing applications to captivate and enthrall audiences.	Evolved AR and VR for business and marketing solutions.
Industrial Applications			

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		• Solve real business problems by using AR and VR for more creative business and marking, such as experiential communication, and collection and analysis of large amounts of data.	
Lowe's Home Improvement	Lowe's Holoroom	• Refocus the experience of the customer on in-store interactions. • Toys are designed with the concept of AR.	Retailers become more serious about AR and VR usage as consumers begin to expect it.
AR and VR	Hammacher Schlemmer	Achieving beacon technology and affordable Virtual Reality by merging AR and VR.	
Virtualized Experiences	Marriott virtual honeymoon campaign	Virtualized experiences, such as virtual weddings, family reunions, and company meetings.	Virtual test drives and vacations.
	Volvo Google Cardboard test drive.		

VR technologies present a consumer media device ripe for new content, such as GearVR, rather than a gaming device. Many have begun to gain notable traction as they work to launch consumer products, such as Microsoft HoloLens, Glyph, Meta, and Magic Leap. However, sales and marketing for AR and VR tend to reference awkward QR code use cases during early explorations, such as playing videos upon scanning QR codes on posters or products, producing an experience that was simplistic or "gimmicky" at best, or disappointing and awkward at worst. The newer approaches create immersive experiences through AR and VR, rather than the current consumer distractions.

Future trends in virtual reality visualization of 3D scenarios

In the recent year, several methods have been adopted to visualize a virtual or real scenario. Certain technologies represent the actual state of new trends due to having been mentioned as the more interesting by consumers among the commonly adopted methods. These are Immersive Video (IV), Nomadic Video (NV), and Head Mounted Displays (HMD).

Table-5. Common technologies for the virtual reality aspects.

Technologies	Descriptions	Advantages and drawbacks
Immersive Video (IV)	360° video applications using a "Full-Views Full-Circle 360° camera."	• Immersive Video (IV) projects multiple images on scalable large screens as multiple images, and can be streamed. Viewers look around as if they are in a real scenario.
Nomadic Video (NV)	A different method of visualization.	• The user can watch video content upon the surrounding context. The display surface toned not be dedicated and/or static (G.Saggio and M. Ferrari,2012). • Nomadic Video allows everyday objects to function as a remote control. A presentation can be controlled by manipulating an object within the camera's field of vision (G.Saggio and M. Ferrari,2012).
Head Mounted Displays (HMD)	Also Helmet Mounted Display (HMD). May be worn on the head of the user as a visor. Equipped with one or two optical displays one or both eyes.	• Lightweight, compact, easily programmed, 360° tracking, cheap, and provides a cinema-like experience. • Significant drawbacks include low field of vision, low resolution, aliasing problems, high latency between user movement and render updates Peripheral details are low.

Several immersive video technologies have been developed that allow "navigation" within a video. As the video plays, the user may explore the scenario in all directions. This approach is based on pico-projectors and Kinect sensors (by Microsoft Corporation). However, HMDs must be worn and adjusted and experts do not recommend them for people 15 years old and younger, due to the overly stimulating imagery, which is dangerous for teenagers whose brains are still developing.

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Future of new virtual reality trends

This section details AutoStereoScopy, AlioScopy, Transparent Displays, and HoloMachine technologies in terms of trend, description, features, and examples.

Table-6. Common technologies for the virtual reality aspects.

Trends	Descriptions	Features
AutoStereoScopy	• Creates the illusion of depth in an image by presenting two images offset for the eyes of the viewer. • Alternative names are 3D imaging or Stereoscopy.	• The human brain integrates the 2D images to create the perception of depth. • The ultimate trend in visualization.
AlioScopy (AS)	The data for every frame must be processed at the same time it is formed by eight images. Current computers have powerful graphic cards capable of processing such large amounts of data.	AlioScopy (AS) systems have great advantages, including immersive experiences of the user with unmatched 3D pop-out and video screens with depth effects. These are attained without uncomfortable eyewear or any kind of glasses.
Transparent Displays (TD)	Transparent displays (TDs) have been used as an efficient tool for delivering information and communication in all industries.	• Display technologies in new devices, such as thin and high quality TVs, touchscreen phones, and sleek tablet PCs. • These panels can be used to show windows, outdoor billboards, and in showcase events. • Companies and schools can use panels as interactive communication devices to display information more effectively.
HoloMachine	• Holography refers to the technique by which the light scattered from an object is recorded and later reconstructed by a beam which restores the high-grade volumetric image.	• Holographic technique presents objects as they are in reality. Users may change position or orientation, as the image appears 3D. • Too expensive and complex for common applications.

Different technologies will be important in future trends of VR, such as AutoStereoScopy and Holomachine. These technologies have produced several trends and great advantages for VR environments. AutoStereoScopy has presented an ultimate trend in visualization. AlioScopy has created an immersive experience whose video has depth. Transparent Display is an interactive communication device that enables information to be displayed more effectively. Holomachine realistically presents objects in any orientation. However, it suffers from being prohibitively complex and expensive.

CONCLUSIONS

Recently, the great goal of VR has been to deceive the five human senses such that user can believe he is in a real environment. VR technologies have become sufficiently cost-effective to be commercially feasible for an increasingly wide range of applications. This paper investigated the trends in VR. We presented a detailed review of VR trends, including previous trends, current trends, and future directions of VR, to provide a unified view of said trends that could serve as a reference for a comprehensive study. We illustrated the previous trends in industrial applications and highlighted their issues and limitations. In addition, we listed and detailed the trends in VR and AR in 2015. We also detailed the future directions of VR trends. In addition, we listed the applications, technological requirements, currently available solutions, and open challenges in VR. Several generalizations were made. Many problems and limitations appeared in the industrial applications of VR technologies, such as HMD and Gloves. The technical limitations are: processing power (processor), image resolutions (imaging), and communication bandwidth (data communication). Other issues which need to be addressed include users, interaction, user effects, and technology. Several obstacles affect current trends, including cost, graphism, resolution (FPS), motion sickness, and high latency. Future studies should comprehensively investigate future trends that provide more realistic experience and immersion in their applications (e.g., military simulations, telepresence in hostile environment or accessible places, aeronautics simulations, moving pictures, and cinema). Also of interest are trends, developments, and issues when of blending AR and VR (e.g., Hololens by Microsoft).

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