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Virtuality Continuum´s State of the Art

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Abstract

In order to have a better and global knowledge of the possibilities for implementing applications based on Virtual Reality and Augmented Reality, a state of the art is presented in this paper. Its purpose is making easier for new researchers or developers knowing the situation and capabilities of these technologies. From the definition of the Virtuality Continuum concept, applications are grouped in those using VR and others applying AR techniques. The ones based on a MR are explained too. Relating to the situation of these technologies nowadays, sectors of application, professional profiles, training offers and standards developed are presented with a prediction of future research lines.

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Keywords: Virtual Reality; Augmented Reality; Mixed Reality

1. Introduction

This paper is intending to deeply introduce the situation of Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR). In the first three sections, each one will be presented in a history, components and tools basis. In section 5, a global vision of the situation of these technologies will be presented introducing the sectors where they are applied, the possibilities to learn about them, the required professional profiles and the standards being developed. Having a global knowledge of the situation, a prediction of the future researching lines will be discussed in section 6. Finally, last section will conclude with the point of view of the author.

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2. Virtual Reality

It produces an appearing of reality that allows the user to perceive a sensation of presence inside of it. It is got through producing a set of images watched by the user through screens, head mounted displays, etc. Some equipment are complemented with wearings and gloves with haptic sensors designed to simulate of different tactile stimuli that intensify the sense of reality. There are several definitions for VR: "Synthetic Reality", "Virtual Worlds", "Cyberspace", "Virtual Environments" and more particularly "Presence" but the most appropriate is the definition that says VR consists of interactive tridimensional simulations reproducing environments and real situation [1]. It is said that a VR application must have these conditions:

1. Simulation, referred to the ability of being a system allowing the representation of a reality;
2. Interaction, to control the system or world represented;
3. Perception, allowing lying to the senses through external elements.

2.1. History

It is a relatively new concept despite of being developed at late 1950s visual devices similar to the ones used in VR applications. But not before the late 1980s it is extended the concept of VR, to be exploited at 1990s by scientific, military, visionary and technologic enterprises. Several of the most relevant projects are shown at table 3.

2.2. Components

• Vision devices: Where virtual world is shown (Computer monitor, laptop screen, TV screen, projector, mobile device screen, tablet screen, video console screen, OPI/MUPI, CAVE, etc.)
• VR SW: Program managing virtual data.
• Interaction devices: keyboard and mouse, joysticks, haptic devices, etc.

2.3. Tools

Despite of the existence of a lot of this kind of tools, some of the most popular tools used to develop 3D virtual environments are mentioned at Table 1.

Table 1. VR Tools

VR Tools	Description
Autodesk 3D Studio [2], Blender [3], CINEMA 4D [4], Autodesk Maya [5]	Modeling, animation, simulation and 3D rendering SW for game, movies and motion graphics developers
Adobe Director [6], Adobe Flash [7], Microsoft Silverlight [8]	Application for multimedia SW development
Ajax3D [9], Java3D [10], X3DOM [11]	X3D [12] based API for 3D development
Away3D [13], Unity [14]	3D engine

3. Augmented Reality

It produces a direct or indirect vision of a physical environment from the real world, whose elements are combined with virtual elements at real time. It generates stimuli at real time for the user's interaction that are superposed over the physical environment of the user. It is made through a set of devices adding virtual

information to the existing physical information this is, physical reality is not substituted but computer data are superimposed to the real world.

These devices use computer vision, object recognition, geolocation and tracking to associate artificial information stored that can be retrieved like an information layer at the upside part of the vision of the real world, making it interactive and digital. Virtual information is added to the physical information to enrich, improve, change and interact with the reality, so we could say AUGMETING REALITY.

AR applications like the ones developed for marketing will need visualization devices, special SW and HW. But capture devices and activators too. Computer vision based AR applications can be marker systems based or marker less systems based. Also there will be applications that use tracking and geolocation. Visualization will be projector based, using head-mounted displays or just with a browser. HW used nowadays is based on low cost microprocessor development boards, videogame devices, smart phones and tablets but also still PCs and laptops are used. There are everyday more and more SW providers that offer development frameworks, browsers, authoring tools and SW libraries [15].

3.1. History

After several VR projects during years from 1960 to 1990, term AR appears in 1992 and then, the first prototypes. From them till 2013, prototypes for Marketing, Tourism, Education, Industry and Entertainment are developed. From 2012, HW and SW improvements are produced and new inputs that make AR popular.

3.2. Components

• Capture devices: getting information from real world (Webcam, laptop webcam, smart phone webcam, video cam,)

• Vision devices: where real images and virtual images are shown (computer display, laptop display, TV display, projector, smart phone display, tablet display, video console display, OPI/MUPI,)

• AR SW: program that mixes images from real world with virtual data.

• Activators: marks that are recognized by the AR SW to insert the virtual data. They are capable of transmit movement and perspective (simple markers, image markers, facial recognition, GPS coordinates, QR codes, NFC…)

3.3. Tools

Besides of the tools used to create 3D virtual worlds and images shown at Table 1, tools shown at Table 2 are used to make the join of real and virtual images.

Table 2. AR Tools

AR Tools	Description
BlippAR [16], Metaio/Junaio [17], MINKO [18], D'FUSION [19], IN2AR [20], Mixare [21], Vuforia [22], AR23D [23], ARToolkit [24], AURASMA [25], GART [26], Layar [27], STRING AR [28], Wikitude [29]	App development for mobile (iOS, Android, Blackberry, Windows Phone, Symbiam)
Kinect for Windows SDK [30], Move.me [31]	App development for console based HW (Microsoft Kinect, SONY PS3 Move)
Gainer [32], Processing [33]/Wiring [34]	App development for HW Arduino
PTAM [35], BuildAR [36], DART [37], ALTERNATIVA 3D [38], SLARToolkit [39]	App development for desktop (MacOS, Windows, Linux)

4. Mixed Reality

Milgram [40] proposed the idea of the Reality-Virtuality Continuum where reality as we know is situated at one side and virtual environments totally generated by computer or VR is situated at the opposite side. Moving from the side of the reality to the side of the VR we could pass by the AR and from the VR towards Reality we will situate at an Augmented Virtuality, AV. Everything between AR and AV is called MR. MR not only allows user's interaction with virtual environments even allows physical objects from the immediate environment of the user to be elements to interact with the virtual environment.

MR will include everything that is not only VR nor AR applications. For example and application developed for giving a virtual scene for broadcasting the weather forecast with a real human over it.

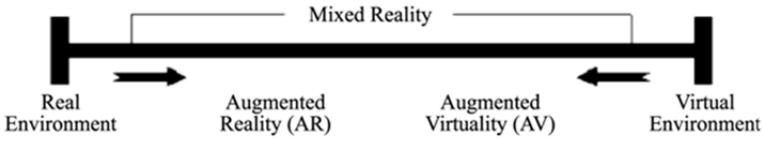

Fig. 1. Virtuality continuum [40]

AR concept involves the combination of different technologies to mix on real time 3D content computer generated with live video recorded with a device [41]. An example of AR could be an application that superposes a synthetic image over a real image; this is done with applications for indoor design that superpose virtual furniture over images with the buildings. MR would be between AR and VR, concerning to different levels of mixture of real and virtual world, integrated on one only visualization device, depending of the weight of its contribution to the final result [40]. An example of AV could be an application that superposes a real image over a synthetic image, the way it is done with virtual stages for weather forecast where the real image of the presenter is superposed over the maps. So it is on MR where techniques such as using physical objects from the user's environment are used as elements for interacting with the virtual environment.

Table 3. History of AR/MR/VR [42] [43]

Project	Sensorama	Philco	Ivan Sutherland	Haptic display	Knowlton, LEEP	DataGlove	Krueger	MIT Media Lab, NASA HMD	NASA VIE Workstation, NASA CRT, USAF, VPL Research	British Aerospace Virtual Cockpit	British Aerospace, W Industries Virtuality	Teletact Globe	AR term and first prototypes	Marketing, Turism, Education, Industry, Entertainment	HW and SW improvements, Smart cities
Data	1956	1961	1965	1967	1975	1981/1982	1983	1984	1985	1987	1990	1991	1992	1990/2012	2012/20XX

5. Situation of AR/MR/VR

In order to give a wide vision of the scope of the technologies presented, this section introduces the sectors where they are applied, the required professional profiles to develop applications based on AR/MR/VR, the possibilities to learn about them and the related standards being developed.

5.1. Sectors

The sectors where these technologies are applied and the services offered will be also pointed. We will group them in: Industrial production systems, Training simulators, Cultural heritage and Centers like museums or thematic parks as shown in Table 4.

Table 4. AR/MR/VR applications [44]

GROUPS	AR/MR/VR applications
Industrial	Visualizing engineering concepts, Training personnel, Evaluating ergonomic issues, Visualizing virtual prototypes, Visualizing virtual weapons, Exploring servicing strategies, Simulating the interaction of assemblies, Simulating the dynamics of articulated structures, Stress analysis, Distributed product development management, Simulating manufacturing processes, Collaborative engineering on large AEC projects, Machining and pressing simulation, Concurrent engineering, Ergonomics, Virtual prototypes, Visual engineering, Spatial visualization.
Training Simulators	Medicine (Soft body modeling, Minimally invasive surgery, Virtual therapy), Civilian flight simulators, Teaching, Learning, Military simulators (Flight, etc.), Strategic simulators, Train driving simulators, Vehicle simulators, Emergency services
Entertainment and Cultural Heritage	Computer and Video Games, Recreational games, Experiences at Thematic parks and Museums, Tourism and Advertisement
VR Centres	Architecture, Indoor Design, Urban Development, Airport Design, Bridge Design, Human Movement Analysis

Several examples of projects and real applications from business and academia will be given. Despite of the two leading formats for AR **learning** experiences given at [45]: augmented books and mobile AR apps, projects such as Avalon [46] that allows learning of Spanish language to foreign students inside a MR environment could be another kind of proposal. Considering **gaming** area, there are two examples with great success: Invizimals [47] developed by Novarama [48] for the SONY PSP video console and ARDefender [49] available for Android and iOS. Recently launched Open Me [50] for video console PSVITA is a promising proposal of video game AR-based. Related to **medicine** AR applied to surgery is described in [51]. There are curious proposals as the **industrial and informational** application from Virtualware for the Spanish Postal service Correos [52] simulating sizes of shipments. Another interesting project for **marketing** is Magic Mirror [53] that is a virtual fitting room that could increase sales of clothes. Duran Duran Project [54] based on gigantic markers shows a projected AR in a concert, so it could be considered an example of **entertainment**. Project Augmented mirror [55] goes beyond allowing real time animation of a virtual character shown to an audience as it is performed by a hidden actor, but there are proposal for Theme Parks [56] and museums [57]. In the scope of **arts**, project ObservAR [58] oriented to museums is an example.

5.2. Professional profiles

The required profiles by companies for working with these technologies are mainly "Developer/Programmer" and "Modeler". The first one must be a computing expert with strong skills programming 3D graphics and interactive devices with several programming languages. The second one should have a background on arts, with capabilities for design and experience with multimedia, modeling, animation, simulation and 3D rendering SW. But profiles mixing capabilities from these two basic profiles are more demanded every day.

5.3. Training

Nowadays several projects are developed at Universities and Academia but there no specific studies for learning these technologies. If we ask for "AR/MR/VR" at the website of ANECA (The National Agency for Quality Assessment and Accreditation of Spain) [59], there are only four Grades/Masters offered by Spanish Universities as shown at table. But there are also other Schools and Colleges that offer related studies.

Table 5. AR/MR/VR grades and masters

University	Grade/Master
Universidad de Granada	Máster Universitario en Desarrollo de Software
Universidad Rey Juan Carlos	Máster Universitario en Informática Gráfica, Juegos y Realidad Virtual
Universidad Europea de Madrid	Periodismo Digital y Redes Sociales
Universidad Cardenal Herrera-CEU	Máster Universitario en Periodismo en Televisión por la Universidad Cardenal Herrera-CEU

5.4. Standards

As long as VR is older than AR, several standards like VRML and X3D have been designed by Web3D Consortium [60] but there are also works in progress for AR. For example, ARML [61] is a proposal. But the big challenge is to compress and stream 3D assets using an effective and widely adopted coder – decoder (codec), in the same way as MP3 is the standard for audio, H.264 for video and PNG/JPEG for images.

Table 6. A Standard 3D Compression Format?

Audio	**Video**	**Images**	**3D**
MP3	H.264	PNG/JPEG	X3D, MPEG4, COLLADA
Napster	YouTube	Facebook	?

6. Future of AR/MR/VR

Having a wide vision of the situation of AR/MR/VR, in this section the seven most promising research lines nowadays will be shown. The first three of them will be HW based (Google Glass, Microsoft Kinect and Mobile apps). The last three will be new concepts (Smart cities, Serious games and Web3D). The one in the middle (Open HW based apps) will be also HW based but also the basis of a new concept.

6.1. Google glass

VR glasses were an icon for this technology but they were relegated due to their manufacturing costs and also because of adaptation issues related to the user. Nowadays there is even researching on contact lens [62], but after Google's advert for its new device called Google Glass [63], expectations for researchers and developers have been triggered because it could be a great opportunity for exploding AR applications. Even new manufacturers have designed similar products as Oculus Rift [64], Atheer [65], Meta [66], Epson Moverio [67], Oakley Airwave [68], Sony HMZ-T1 [69], Vuzix [70], Glass Up [71] and Eyeborg Eyecam 3.0 [72]. These products give a second chance to VR glasses. Other devices for allowing us to walk through virtual worlds the way we do on real world are the perfect complement for these visualization gadgets, Omni [73] is the most clear and recent example.

6.2. Microsoft Kinect

This device manufactured by Microsoft as a complement for its video console XBOX 360 has been supporting development of AR applications at labs researching new HCI ways and also for companies developing interactive products. Projects for therapies as Virtualrehab [74] or Toyra [75] oriented to physical rehabilitation have been developed using this device that monitors color, depth and audio. Also it could be used as a biometric controller as announced for the next generation XBOX ONE console. It has been the base of projects for sign language recognition [76] and recently a SW for turning any surface into a touch screen has been presented by Ubi Interactive [77] using Kinect and a projector. Of course, competitors have appeared as SONY Playstation 4 Eye [78], Leap Motion [79], MYO [80], Omek [81] and Tobii [82].

6.3. Mobile applications

Smart phones and tablets with their powerful HW and small sizes are the perfect support to develop mobile devices with AR/MR/VR capabilities. The wide and increasing range of apps developed for the most popular operating systems for mobile and tablets (iOS, Android) based on these technologies could be enough to give us an idea of the growth of these kind of apps [83].

6.4. Open HW based applications

With open HW represented by Arduino [84] and Gainer [85] professional and amateur developers can make true devices in a cheaper way than years ago when high costs in HW were only affordable for great companies. Besides, 3D printing allows manufacturing of elements to interact with this HW in an easy way. These are the basis of the so called "Internet of things".

6.5. Smart cities

Based on definitions given for AR/MR/VR, a city is a perfect stage for applying these technologies. This way, smart cities are being a line of research for these technologies. Wireless technologies, networked infrastructures, improved travel solutions, rational and coordinated use of resources, social inclusion, and increased competitiveness are all implicated in the advent of smart cities. A smart city is not only a city full of sensors, cams and lights controlling everything. It is about adapting use of technology to improve citizens' life. The target is getting the optimum management of resources and giving a greater accessibility to different services. A Smart City improves and integrates sectors and transport subsystems with others like education, health, security, entertainment, commerce and public services. Use of data generated by smart cities and our capability to use them are deeply related with the use of Big Data to make easier the treatment of those data and make them useful information. The goal is to understand what the city is telling us, being able to translate all these data to have a more efficient management for the citizens. Here resides the role of AR/MR/VR that can be outstanding when showing the data if we assume the quote "a picture speaks a thousand words". An example is SmartSantanderRA [86].

6.6. Serious Games

Videogames still are a target for these technologies, but recently the use of a new way of learning is growing. It is called gamification. It consists on applying videogame's philosophy to other aspects of the real life as managing, learning, etc. This is why serious games are more important every day with examples as

Delfos3D Project [87]. Of course, AR/MR/VR form an alliance with marketing, advertising and simulation to develop this kind of projects.

6.7. Web3D

Despite of considering Second Life [88] a failure, Web3D is the future. An example of this could be the success of Minecraft [89], it could be considered a simply "digital LEGO" where remote users build structures with blocks in a virtual world. Even more and more websites are tridimensional. There are several project developing APIs based on X3D [12] as shown in Table 1 helping programmers to build 3D websites. This will be generalized when our smart phones and tablets will be able to visualize these characteristics because these devices will be the ones to give the bigger percentage of accesses to the Internet. Regarding this line, Metaio with Sony Ericsson has developed specific HW to process graphics on future platforms [90]. Definitely standardization of a 3D compression format (see Table 6) will give a bush to the massive implementation of Web3D.◀

7. Conclusions

In this paper, AR/MR/VR technologies have been presented with related components, history and tools. After revising sectors of application, professional profiles, training offers and standards, future of related research lines have been predicted. All in all, we can assure that these technologies are part of our lives more than we can imagine. Despite of it and considering a lot of sectors with needs to be covered, there is a promising future not only for professionals who are beginning development of new projects related with these technologies, also for those exploiting and implanting applications together with the ones teaching related knowledge and capabilities. Despite of the investment on training for developing applications based on AR/MR/VR, the solutions that can be reached are less expensive than solutions proposed before, not only relating to money, also talking about sustainability. As an illustrative example, augmented books are cheaper to develop than paper books and there no need of deforestation.

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