A Short Review of the SDKs and Wearable Devices to be Used for AR Application for Industrial Working Environment

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***Abstract*— During the last two decades, and especially the last few years, augmented reality helps workers manage safety risks on site and prevent injuries and increase the efficiency of safety. This review on the presently existing SDKs and their features is aimed at finding the most efficient AR SDK that would be suitable and would correspond to the purpose of the AR application for industrial working environment in terms of safety. The summarized information of the world's most widely used platforms for AR development, with support for leading phones, tablets and eyewear, SDKs presently available on the market is intended to help developers to create their AR application as well as to which parameters one should pay attention to, when building augmented reality applications for industrial use.**

***Index Terms*— Augmented Reality, ARSG, IoT, Software development kit, Safety,**

I. Introduction

WORKPLACE safety appears to be a massive global problem. In line with the recent research trends, Augmented Reality (AR) is one of the emerging technologies involved in the new Industry environments. Presently, it is considered to be ready for being used within the industrial working environments. The production processes may generate problems which make the operations less efficient and potentially dangerous for the workers during their work. The main problems are:

(a) Human error: even the most experienced workers can make mistakes due to the high number of procedures to be remembered and the difficulty in identifying the precise points of intervention.

(b) Inefficiencies: due to inadequate training received by engineers and poor access to statistics on the operations carried out. Also very often paper manuals used for training are not updated, thus creating further confusion.

(c) Costs: errors and inefficiencies involving higher personnel costs, longer execution times, recurring errors and accidental damage to components due to incorrect execution of the procedures.

Manuscript received July 20, 2018; revised July 29, 2018.
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During the last two decades, and especially the last few years, augmented reality helps workers manage safety risks on site and prevent injuries and increase the efficiency of safety.

In this convergence of the physical and digital world, AR technologies like smart manufacturing, internet of things, additive manufacturing, machine learning, and digital twins are creating new opportunities for innovation. All those trends are part of the combination of traditional manufacturing and industrial practices with the technological world in the fourth industrial revolution - the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing that connect the internet of things (IOT) with manufacturing techniques to enable systems to share information, analyze it and use it to guide intelligent actions

Augmented Reality has the potential to provide far more value to today's workplaces. The possible use cases of AR are different and may be applied in almost all activities taking place in the factories. The main scenarios can be in production, quality control, safety management, maintenance and remote assistance, training of workers, logistics and design. AR can integrate digital information into the ways in which workers perceive the real world, enabling them to seamlessly use that information to guide their choices and actions in real time, as they accomplish tasks.

Augmented Reality is not just one technology. It is the combination of several technologies that work together to bring digital information into visual perception.

AR services use various device sensors to identify the user surroundings, bringing different experiences to life through portable devices, smart glasses and AR headset. That becomes part of daily experience with mobile computing systems.

The aim of this paper is to identify the most efficient AR platform for the purpose of an application which enables users to visualize through an augmented reality device a product or machine, so that to help managing the safety risks in working environment. The digital representation provides both the elements and the dynamics of how an Internet of Things device operates and allows users to view an exact digital representation of a product overlaid on top of the physical one, visualizing all kinds of information and details on all the sensors on the device.

The main idea of the present paper is to make a summary and to find the most efficient AR SDK that would be suitable and would correspond to the purpose of the AR application for industrial working environment in terms of safety, through a review of the existing literature on the presently existing SDKs and wearable devices. This is planned to be achieved using the quick and dirty method in order to find the most appropriate and cost efficient solution.

This paper aims also to help developers to create their AR application using the summarized information about the most widely the world's most widely used platforms for AR development, with support for leading phones, tablets and eyewear, SDKs currently available on the market. Additionally, to indicate the criteria one should pay attention to, when building augmented reality applications for industrial use.

Object detection, object tracking and action recognition are the key issues in finding technical challenges and potential issues when applying computer vision-based approaches in practice.

The paper is organized as follows: in section two is introduced the term SDK, evaluation criteria, and comparison of the features of chosen the SDKs is made. In section three wearable devices and their features are compared. In section 4 finally some conclusions regarding the choice of SDK and the wearable device are made.

II. SDK Research and Comparison

The aim of the paper is to identify the most efficient AR platform for the purpose of an application able to overlay digital content on top of the physical. An SDK is a set of programmes providing a set of tools, libraries, relevant documentation, code samples, processes, and or guides that allow developers to create software applications on a specific platform. [1] It allows the programmer to interact more easily with some of the native capabilities on the different OS platforms in order to create/deliver/serve augmented reality experiences. The first point in reaching that goal is stating the criteria upon which the different SDKs should be compared in finding the one that best suits the application. This is an important step when choosing an SDK as its specifications and should support all the features of the wanted application. There are several major criteria which are outlined below.

a/ Type of license That's what any company should consider first. As usual, there are free and commercial/ enterprise licenses. Needless to say, free functionality is usually rather limited, so a commercial license is required to build a function rich mobile application. There is also open source augmented reality software, to which developers can contribute and add more functions.

b/ Supported platforms When choosing an augmented reality SDK, the platform with which it works should be checked. Of course, nearly any SDK supports both Android and iOS (the two most widely used mobile operating systems). Some AR SDKs are compatible with the Universal Windows Platform (UWP) that will help to create AR apps for Windows-operated smartphones and computers. There are also augmented reality platforms that allow you to develop AR apps for mac OS.

c/ Smart glasses support Today, most AR applications function through smartphones and tablets, which means consumers can see virtual objects on the screens of their devices. However, there is a different way to overlay AR objects right on the real world: smart glasses. Unlike smartphones, smart glasses allow hands-free AR experiences. Since smart glasses are becoming more popular (Microsoft HoloLens, Vuzix Blade 3000, Epson Moverio BT-300, and many more), being able to build AR mobile apps compatible with these gadgets is certainly an advantage.

d/ Unity support Unity is one of the most advanced game engines in the world. Typically, it's used to create games for computers and consoles, but Unity is also capable of powering many other augmented reality apps. It is a cross-platform engine that enables you to build apps for multiple platforms including iOS and Android and UWP. Many SDKs are compatible with Unity which brings performance optimizations, tight ongoing synchronization of features and fixes, and a native Unity workflow that enables developers to create the best AR experiences using a simple authoring workflow and event-driven scripting directly in the Unity Editor. It is a plus if supported.

e/ Cloud recognition If there is a need to create an AR mobile app capable of recognizing lots of different markers, it is important to check whether an augmented reality development kit supports cloud recognition. With this feature, markers are stored in the cloud, while an application doesn't require much space on a mobile device. Another important aspect is the number of markers that can be recognized. Some augmented reality development kits support 100 markers, but others can recognize thousands of them. Needless to say, the more markers AR development software can recognize, the more advanced the AR experiences will be created.

f/ On-device (local) recognition In order the software to be more versatile the online and offline feature is important. Through the on-device (i.e. local) markers are stored right on a user's portable device, so there's no need to go online to use the app. In this way it supports better user needs in different situations.

g/ 3D tracking Top augmented reality platforms support 3D image tracking, which means they can recognize 3D objects, such as cups, cylinders, boxes, objects, and more. This immensely expands the opportunities for augmented reality in the mobile apps.

h/ Geolocation Essential for creating location-based AR apps. For example, if there is need to add virtual points of interest to the application, an augmented reality platform with geolocation support will be a must.

i/ SLAM stands for Simultaneous Localization and Mapping. The core of this technology is quite simple: SLAM allows applications to map an environment and track their own movements in it. For example, an AR mobile app can remember the position of different things in a workshop, or factory and, thus, keep a virtual object in a certain place while a user moves around the room. Also, this technology can go far beyond adding AR objects. Thanks to SLAM, it's

ISBN: 978-988-14048-1-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

possible to create maps for indoor navigation. GPS doesn't work indoors, but SLAM does, so this technology has enormous potential.

Following the review of the SDKs a table is made according to the above criteria. For the purpose of this paper one of the most comprehensive SDKs are compared according to the features they possess. In a search for an appropriate solution the following AR SDKs are compared – Wikitude, Maxst, Vuforia, ARcore, ARKit, EasyAR and Kudan. Some additional features are added to the table to achieve a more detailed and complete comparison.

The research done shows that all SDKs possess similar features. All of them are very well developed and able to bring top of the class augmented reality experiences. However only Wikitude, Vuforia and EasyAR meet all the criteria for the purpose of the paper.

Exploring SDKs is an important step when moving into AR. To choose the right one, one will want to look first at in-house development capabilities, familiarity with software tools, cost, how deeply the tool has been developed, and how broadly it has been adopted. Entirely different, one can choose codeless authoring and publishing tool.

The only AR platform currently on the market exclusively focused on enterprise is Vuforia Studio. Made by PTC, the team behind the Vuforia SDK, Vuforia Studio makes sense for software engineers who wants to:

•Rapidly develop AR experiences specifically for connected products in manufacturing and industrial enterprise

•Do so with less programming because Vuforia Studio takes advantage of existing 3D assets and CAD renderings PTC has been collecting since the 80s

• Create step-by-step instructions and animated sequences to make work easier and faster

• Create virtual interfaces on machinery and other connected products that provide a real-time view of data

• Visualize existing 3D data in the real world to enhance design reviews, expedite the learning process, and improve safety.

This is a drag and drop environment that allows you very quickly author and publish AR experiences that can be used to communicate with AR content in variety of use cases.

III. Wearable devices/ Headsets

In the working environment, however, the real added value of AR is its ability to make insights from machine intelligence available to the average worker. Most AR systems currently deployed are tablet- or smartphone-based, although some are now moving aggressively in the direction of head-mounted displays (HMDs) that allow the worker to access AR data continuously without interrupting a task to refer to a tablet display.

Display Devices

There are three different types of technologies: Video see-through, Optical see- through [4] and Projective based. The video see-through is closer to virtual reality (VR), the virtual environment is replaced by a digital video of the physical world and the virtual content is superimposed on the video frame. The optical see-through allows to have a greater perception of the real world, contents in AR are superimposed through mirrors and transparent lenses. The projection based technology allows to project the digital content directly on the real object.

Video See-Through. Video see-through is the most economical technique and offers many advantages; (a) The devices that use this technique may be HMD or mobile device (smartphone or tablet); (b) the current environment is digitized (via video) and it is easier to interact with the real world by superimposing virtual objects; (c) the brightness and contrast of the virtual objects can be easily adapted in the real world; (d) it is possible to match the perception of delay between the real and the virtual environment.

The main disadvantages are: (a) the low resolution of the camera; (b) the limited field of view; (c) in many devices the focus distance cannot be adjusted; (d) In HMD devices, the user may be disoriented because the camera is near the eye positioning.

Optical See-Through. Optical see-through technique is applied to the HMD devices, AR content is mirrored on a curved planar screen. The main advantages are: (a) the display is ideal for a long period of use as it does not create discomfort effects on the user and leave unchanged the real vision; (b) the user has a direct, unmodified view to the real world, without any delays; the AR objects depend only by the resolution of the display. (c) They have a low energy consumption compared with see-through video. The disadvantages are: (a) the projection of images on the lenses has a contrast and brightness reduced therefore are not suitable for outdoor use; (b) The reduced field of view can lead to the leakage of the projection from the edges of the lenses; (c) it requires difficult and time- consuming calibration (user- and session-dependent).

Projective. Projective technique is based on the projection of the digital content on real world objects. The advantages are: (a) it does not require lenses to wear; (b) it allows to cover large surfaces generating a wide field of vision. The main disadvantages are: (a) the headlamp shall be recalibrated if the surrounding environment or the distance from the projection surface changes; (b) it can be only used in indoor environments because of the low brightness and contrast of the projected images. [3]

Evaluating the wearable devices The industrial workshop or factory is generally a high-risk environment with automated machines, robots, trucks, chemicals, etc. The wearable devices used to realize augmented reality have strengths and weaknesses, depending on the purpose of the particular application. For the industrial workplace, glasses are generally very useful since they free the operator's hands and are mobile and easily portable. There is a wide variety of Augmented reality smart glasses

ISBN: 978-988-14048-1-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE I
SDKs COMPARISON.

Features	Wikitude	Maxst	Vuforia	ARCore	ARKit	EasyAR	Kudan
Slam	6-DoF SLAM	Visual slam- only uses camera.	VIO	Concurrent odometry and mapping COM, IMU	Visual Inertial Odometry VIO, IMU	Monocular real-time 6 DOF camera pose tracking	6 DOF camera pose tracking
Plain Detection	+	Recognizes horizontal plane in using camera and inertial sensor.	+	Horizontal, vertical angled surfaces	Horizontal, vertical angled surfaces	+	+
Support ARCore/ ARKit	+	–	+	–	–	–	–
Hit testing	+	n/a	+	+	+	n/a	n/a
Marker	+	+	+	-	-	+	+
3D Object scene, recognition tracking	+	You can import map files created with Visual SLAM to enhance desired content.	+ Model targets	Placing virtual objects with anchors	3D object detection and persistent experiences.	3D Object tracking	+
Extended tracking	+	+	+	+	+	+	+
Image tracking recognition	Offline up to 1000 +	200 images 0.2 sec, 1.2 m	Offline up to 1000 +	Offline or added in real time from device	+	Up to 1000 offline targets Unlimited recognition	+
Multiple image targets	+	Up to 3 images	+	+	n/a	track multiple targets	+
QR code	+	+	+ Vumark	–	+ Vision framework	+	+
Cloud image recogn tracking	+	–	+	–	–	+ 100K	–
Location based services	+	–	+	–	–	–	–
Device OS	Android, iOS, UWP	Android, iOS, UWP	Android, iOS, UWP	iOS	Android	Android, iOS, UWP	Android, iOS
Development tools and platforms	Unity3D Plugin, Cordova plugin, Titanium Module, Xamarin Component	Unity3D Plugin	Unity3D NDK Gradle Android SDK Build Tools Android Studio Xcode, Visual Studio	Xcode	Android Studio NDK Ureal Unity3D	Unity3D, C API, C++11 API, Traditional C++ API Java API Swift API Objective-C API	Unity3D Plugin, Objective-C API Java API

TABLE II
PRICING OF SDK.

Pricing	Supported Features	Wikitude	Maxst	Vuforia	ARCore	ARKit	EasyAR	Kudan
FREE watermark	Full Limited	+ Free Startup	+	+	+	+	+	+
One Time Fee	Full Limited Full	Demo€499 Pro€1990 Pro3D€2490	$499	$499	–	–	$500	–
Per Year	Full Limited	€2990 * €2490 *	$599	–	–	–	–	$1350 **
Cloud recognition	Full	€4449 *	_	1188	_	_	+	

(ARSG) . Some of them have a simple headup display that serves as a second screen accessible at a glance, whereas others implement more complex solutions such as retinal projection or holographic display. The following five parameters relevant to an industrial environment are considered as main ones : (1)

ISBN: 978-988-14048-1-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

powering, (2) weight, (3) field of view, (4) battery life, and (5) optics.

Powering ARSG can be powered in two ways, through either a battery pack or an ordinary computer. For the working environment, battery power is essential as it is impossible for an operator to carry a computer throughout the workday.

Weight Since ARSG are meant to be worn more or less the whole day by operators, their weight is critical. A pair of normal glasses weighs about 20 grams, but no ARSG available today are even close to this weight. To be realistic, we set the recommended upper limit to 100 grams (about five times the weight of normal glasses) to allow most users to wear the glasses for at least a few hours.

Field of view The field of view is the area in which virtual objects can be seen via the ARSG, and is a crucial parameter as it directly indicates how much information can be shown to the user and where it can be placed. The horizontal field of view is very important. A human’s natural field of view is almost 180 degrees horizontally, but today’s ARSG are far from matching this. A a realistic, acceptable minimum field of view in ARSG is accepted to be 30 degrees (horizontally).

Battery life An industrial operator is supposed to wear ARSG throughout the working day and a durable battery is necessary to enable this. For the integrated batteries, the battery life must be at least 9 hours, or if they can be fast charged – 4 hours (can be recharged in the lunch break).

Optics Three types of optics can be implemented in ARSG for visualizing information: video, optical, and retinal projection. It is considered that for the industrial environment, a product that implements an optical or a retina-based solution should be selected, and video-based solutions should be avoided because video-based solutions have latency in what the user sees compared with what is really happening.

Other important criteria include: the camera of the glasses; open API; audio - microphone and speaker – important for communication; sensors – depends on the need of the application and may be gyroscope, compass, GPS, and head or gesture tracking; controls – should be hands free and usually is through voice commands; processors - should be minimum dual core; storage – minimum 30 GB; memory – minimum 2 GB; connectivity – WIFI to connect the glasses to the Internet or local network. etc. [4]

TABLE III
PRICING OF SDK.

Model	ODG R-7+	HoloLens	Epson BT-200	Epson BT-300	Epson BT-350	Vuzix M300
Field of view	30°	34°	23°	23°	23°	16.7°
Battery life	Up to 6hours		6 h	6 h	6 h	2- 12, external battery
Optics	Optical see-through HD display	Optical see-through	Optical see-through 24-bit QHD color display	Optical see-through 24-bit HD color display	Optical see-through 24-bit HD color display	Video see-through, nHD display
Camera	Autofocus 4MP	2 MP	VGA 0.3 MP	5 MP	5 MP	Up to 10MP
Sensors	IMU, gps in controller, Humidity, altitude, GPS	IMU, 4 camera , 4 microphones, ambient light sensor	IMU, gps in controller,	IMU, gps in controller, light sensor	IMU, gps in controller, light sensor	IMU
Controls/memory	Track pad, voice control 64gb	64 gb, gesture, voice	8-GB flash, touch pad voice control	16-GB internal storage, track pad	16-GB internal storage, track pad	64GB, 4 buttons, voice control, touch pad, gestures
Processors	Qualcomm Snapdragon 805 2.7 ghs quad-core	Custom HPU 1.0, Intel 32-bit	OMAP 4460 1.2GHz dual-core	Intel atom 5 1.44 quad-core	Intel atom 5 1.44 quad-core	Intel atom dual core
Connectivity	Wi-Fi 802.11 c/a Bluetooth 4.1	Wi-Fi 802.11 c/a Bluetooth 4.1	Wi-Fi 802.11b/g/n Bluetooth 3.0	Wi-Fi 802.11b/g/n/ Bluetooth 4.0	Wi-Fi 802.11b/g/n/ Bluetooth 4.0	Wi-Fi 802.11b/g/n/ Bluetooth 4.1
Weight	170	579g	96g	69g	69 g	
OS	ReticleOS (Android base)	Windows 10	Android 4.0	Android 5.0	Android 5.0	Android 6.0
Platform support	Vuforia	Vuforia	Vuforia	Wikitude	Wikitude	Vuforia

IV. CONCLUSION

Software components

Unity framework and Vuforia SDK are suggested as most appropriate and efficient for the purpose of creating an application that is to be used in industrial working environment.

Unity 3D Game Engine is a system that allows the development of multiplatform games developed by Unity Technologies that includes a game engine and an integrated development environment (IDE). Supported platforms include BlackBerry 10, Windows Phone 8, Windows, OS X, Linux (mainly Ubuntu), Android, iOS, Unity Web Player, Adobe Flash, PlayStation, Xbox and Wii. The development environment allows to create and manage 3D objects and create simple mobile application.

Vuforia AR SDK. Vuforia represents one of the most advanced solutions for the development of AR applications for mobile devices. Vuforia SDK is subdivided into two SDK dedicated to the development of Android and iOS platforms, respectively; Vuforia Unity Extension is also available that allows to use the Unity environment to manage advanced functions for creating augmented reality applications, and all the prefab objects useful for the creation of three dimensional scene; also allows the release of apps for both Android iOS platforms. The strength of this SDK is given by the possibility of identifying and tracing different types of targets: (a) Image target consists of a simple two-dimensional color image; (b) Cylinder Target (c) Multi Target allows to track multiple targets (as long as a portion of the multi-target track is recognized for all others); (d) Frame Markers are special markers that are identified by a unique code; (e) Object Recognition allows to recognize solid three-dimensional objects. Vuforia provides an online tool that allows to calculate the image quality to target and have it in a suitable format for use in RA. Finally it provides a cloud platform where target images can be saved (or can download directly on the device). Vuforia SDK is offered with a freemium mode, where all the features can be used in development mode but a license is needed if the application will be on the market.

Hardware components

After appropriate research among the available models the conclusion is that the ARSG that could be used should have the following hardware features: display with at least resolution, 2 GHz, dual core CPU, 2 GB RAM, 30 GB Internal Memory with an external slot, camera at least 5MP camera with 1080p video recording, speaker and noise canceling microphone, microUSB port, WI-FI and blue tooth 4.0 connectivity support. The device should be equipped with buttons, two for scrolling forward and back, one for selection and one for switching on and off. It should has a voice recognition system using proprietary libraries but expandable. The operating system should be compatible with the Vuforia SDK. Battery life is to be at least 6 h.

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