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Project Deliverable 2.4

Technology Monitoring: Report on Information Needed For Workers in the Smart Factory

Worker-Centric Workplaces in Smart Factories

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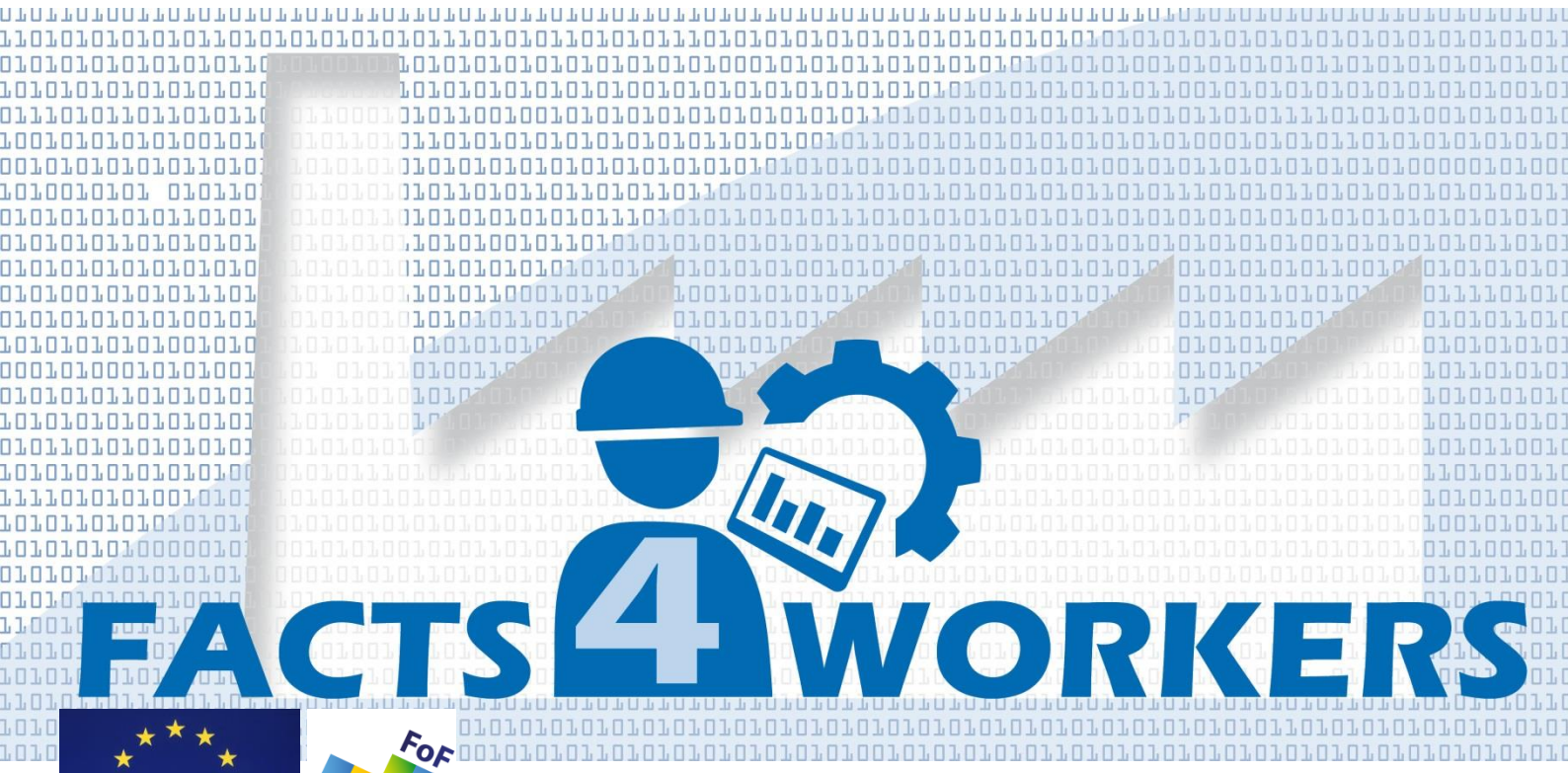

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About this document

Executive Summary

D2.4, Technology Monitoring: Report on information needed for the Industrial Challenges workers with taxonomy is part of the work in progress of FACTS4WORKERS. T2.1 is an activity of WP2 aiming to highlight the current state of the applicable technologies (both hardware and software) which can be used for implementing Worker Centred Industry 4.0 solutions, which are already applicable and under which risks.

D2.4 takes as base the previous three reports as base for determining if available AR technologies can be used of shop-floor for supporting workers task and, which are the limitations presented by them.

As it made D2.3, this report use the methodology defined in D2.1 and D2.2 for assessing the TRL of available technologies (software and hardware) in consumer environment and industrial environments. In addition, as mobile systems are mature enough for being used on shopfloor, D2.4 and D2.3 only focus on AR technologies as they are key-enablers of the Industry 4.0 vision.

D2.4 updates previous version of FACTS4WORKERS taxonomy of HCI technologies. The taxonomy is used for determining the current TRL of AR systems but also for presenting the evolution of the technologies during the last four years. This evolution is aligned with Gartner 2015 Hype-cycle and it is used for presenting the main risk and limitations of AR technologies. However, our conclusions are enriched with the comments from shop-floor workers which are gathered from them during the evaluations of the deployed prototypes. These comments and other more general about the introduction of Industry 4.0 worker centred solutions can be found in D6.3 and D6.4 available on FACTS4WORKERS web site. Lacueva Perez, F. J.,

Keywords

HCI critical taxonomy, Industry 4.0, Factory of The Future, Shop floor, Smart devices, Wearables, Augmented Reality.

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App.....Application

B/M.....Binocular/Monocular

CP.....Cross-Platform

DOD.....Department of Defense

ESA.....European Space Agency

FoV.....Field of View

GAC.....Gyroscope, Accelerometer, Compass

HCI.....Human Computer Interaction

HMI.....Human Machine Interaction

NASA.....National Aeronautics and Space Agency

NF.....Natural Feature

OSS.....Open Source Software

OST.....Optical See Through

SaaS.....Software as a Service

SDK.....Software Development Kits

TRL.....Technology Readiness Level

UC.....Use Case

VS.....Visual Search

1 Introduction

D2.4, Technology Monitoring: Report on information needed for the Industrial Challenges workers with taxonomy is part of the work in progress of "FACTorieS for WORKERS" (FACTS4WORKERS). It is the result of the execution of T2.1 in 2018. T2.1 is an activity of WP2 aiming to highlight the current state of the applicable technologies (both hardware and software) which can be used for implementing Worker Centred Industry 4.0 solutions, which are already applicable and under which risks.

D2.4 is the fourth and last update of the document D2.1 which presents a vision of the HCI technologies that supports the implementation of the building blocks, presents the methodology and the taxonomy created within the FACTS4WORKERS project and the technological updates introduced during the year.

The methodology and taxonomy have been widely covered in the previous versions of the Document so readers interested in this section and the procedure carried out in its creation, please, review the referred versions.

As in the previous revisions, we have focused, in this document, on the augmented reality technologies as we consider this mainstream as one of the biggest challenges in the Industry 4.0. In this document, we present an update of the SDKs and the devices and we summarize the efforts made in the industry in this period and how these technologies could support and empower workers on the shop floor.

Therefore, the D2.4 structure covers the AR SDK updates with new features in Wikitude 8, ARKit 2 and Vuforia. In this section, we list the most popular SDKs present in the ecosystem with their main features and characteristics.

In the next section, we present the smart glasses market where vendors have increasingly become aware of industrial requirements and consequently tried to integrate them in their newest hardware devices. Additionally, we present a new smartwatch, Workerbase, which is directly aim at industrial use.

To end, we will summarize the overall development of the market during the project time framework and we will present the general conclusions.

2 AR SDK updates

As we presented in the previous monitoring report, D.2.3, in 2017 big players like Google and Apple announced their SDKs in the branch of Augmented Reality. This was a significant advancement in order to make these SDKs available to the developer's community to create AR applications in many fields.

We presented in detail Tango, ARCore and ARkit. During this year some updates have appeared but with less impact. For instance, in July 2018, Wikitude released the latest version of powerful SLAM solution for augmented reality apps called Wikitude SDK 8.

Wikitude SDK 8

This new version offers new characteristics like the ones mentioned below:

- Scene recognition (augment large objects for outdoor gaming, construction, etc.)
- New extended recording and tracking of objects (scan and see augmented objects beyond markers)
- Instant targets (save and share instant augmentations)
- Unity live preview (AR-view feature into Unity editor to test the SDK features)
- Windows support

Additionally, in June 2018 Apple launched a new updated version – ARKit 2, coming out along with and for iOS 12. The new improvements presented in this second version of the SDK are the following:

ARKit 2

- Persistent and multiuser experiences - AR experiences can now be shared across time and fixed to real-world locations, so you can create a piece of AR art that can be viewed later in the same place by someone else.
- 3D object recognition - ARKit 2 recognizes objects and how your device is oriented to them and can use that information to incorporate objects into AR experiences.
- Face tracking - Face tracking now sees where you're looking and can detect whether you're sticking out your tongue or winking.

- Scene reflection - Enabling virtual objects to reflect the real-world scene in your camera.
- USDZ file format - A new format that helps 3D creators to create content and animations optimized for mobile devices.
- AR Quick Look - View AR experiences in apps, including Files, Mail, Messages, and Safari.
- Measure app – Allows using the iPhone or iPad camera to measure objects and surfaces both vertically and horizontally as well as automatically detecting dimensions of rectangular objects.

Another relevant updates in the world of SDK are the releases of Vuforia. Vuforia has released new advanced editions – Vuforia 7 (December 2017) and 7.1 (March 2018), Vuforia Engine 7.5 (September 2018) presenting these capabilities for AR content:

Vuforia

- Vuforia Model Targets – introducing object recognition by shape, contrary to visual print media designs. This will help track images, scanned objects, special marks (encoded), text and surfaces.
- Vuforia Ground Plane – a feature for Unity engine that allows to place the augmented content on ground or surfaces. It helps to create high-quality visual apps and designs.
- Vuforia Fusion – a feature aimed at solving the fragmentation and enabling cameras, sensors, as well as external frameworks, e.g. ARKit.
- Vuforia Updates – a bunch of improvements on v.7 release, including automatic initialization on scenes with Vuforia components, option to clone objects, support ARCore, HoloLens and Universal Windows Platform devices and more.

As a summary of these years in the AR toolkits ecosystem, we include the following summary list which shows the most used sdks with their main characteristics.

2.1 Vuforia

Vuforia is an Augmented Reality platform which recognizes the 2D planar image as well as different types of visual objects (a box, cylinder, plane), text and environments recognition, VuMark (a combination of picture and QR-code).

Supported platforms: Android, iOS, UWP and Unity Editor and Smart Glasses.

Features:

- Mixed Reality and Eyewear Support including Microsoft HoloLens.
- Recognize and track a broader set of objects, Image.
- Vuforia Ground Plane will be included in Unity as part of a new free deployment option.
- Natural Interactions with Virtual Buttons
- Vuforia Object Scanner
- Model Targets: CAD based detection to detect real-world objects like a car, bike, machine etc.

2.2 ARkit

ARkit is a framework that allows creating unparalleled augmented reality experiences for iPhone and iPad by blending digital objects and information with the environment around.

ARKit runs on the Apple A9, A10, and A11 processors and uses Visual Inertial Odometry (VIO) to accurately track the world around it. VIO fuses camera sensor data with Core Motion data. ARKit can detect horizontal planes like tables and floors, and can track and place objects on smaller feature points as well.

Supported platforms: iOS, Metal, SceneKit, and third-party tools like Unity and Unreal Engine.

Features:

- TrueDepth Camera
- Visual Inertial Odometry
- Scene Understanding and Lighting Estimation
- High-Performance Hardware and Rendering Optimizations

2.3 Google ARCore

ARCore is the Google AR platform. It is built on Tango technology and makes AR available across Android phones without having to add any additional hardware.

Supported platforms: Android Studio, Unity, Unreal Engine, Web

Features:

- Environmental understanding: Allows virtual objects to be placed in a way that physically connects with the real world.
- Motion Tracking: Allows users to walk around and interact with virtual content that is rendered in the 3D world.
- Light Estimation: Create realistic looking objects by having its own light change dynamically according to the environment lighting.

2.4 Wikitude

Wikitude is a cross-platform Augmented Reality SDK which combines 3D Markerless Tracking technology (SLAM), Object Recognition and Tracking, Image Recognition and Tracking, as well as Geo-location AR for apps. Wikitude SDK is a commercial solution but is also available as a trial version with some limitations.

Supported platforms: Android, iOS, Unity Editor, Smart Glasses, JavaScript, etc.

Features:

- Image recognition & tracking
- Object Recognition
- Instant Tracking
- 3D tracking technology (SLAM-based)
- Cloud recognition

2.5 ARToolkit+

ARToolKit+ is free and open source augmented reality SDK which supports top-notch Image Recognition and Tracking. ARToolKit+ supports new features, like Database(ImageTarget) manager, Robust camera calibration, NFT real world image tracking, Cross-platform development through unity plugin and much more. ARToolkit is an open source SDK and complete source code is available on GitHub.

Supported platforms: Android, iOS, Unity Editor.

Features:

- Robust Tracking, including Natural Feature Tracking

- Strong Camera Calibration Support
- Simultaneous Tracking and Stereo Camera Support
- Simple to use unity plugin: without prior registering targets
- Full Unity3D and OpenSceneGraph Support

2.6 EasyAR

EasyAR presents an SDK, which offers a number of features, such as SLAM, 3D tracking, and screen recording (some of them in the paid version of the SDK).

Supported platforms: Android, iOS, Unity Editor and UWP.

Features:

- 3D Object Recognition
- Environment perception
- Cloud Recognition
- Smart Glass Solution
- App Cloud Packaging

2.7 MaxST

MAXST AR SDK is an augmented reality engine that integrates a variety of features including Image Tracker, Instant Tracker, Visual SLAM, Object Tracker and QR/Barcode Scanner into an all-in-one package.
Maxst AR focuses specifically on Natural Feature Tracking, and provides a fairly wide range of deployment platforms, including the Moverio smart glasses.

Supported platforms: Android, iOS, Unity Editor, and SmartGlasses.

Features:

- Fast and robust recognition/tracking performance
- Multi-platform supported: Android, iOS, Mac OS, Windows
- Easy to implement various visual effects
- Smart glasses supported: Epson Moverio BT-200, 300 and ODG R-7

3 Smart Glasses

As in the years before, we could recognize a clear focus on industrial application areas during monitoring the smart glasses market. Vendors became increasingly aware of industrial requirements and consequently tried to integrate them in their newest hardware devices. Along with this trend, some devices have been withdrawn from the market (some even before they have been originally released). Additionally, a new category of devices, so called mixed reality smart glasses, experienced a boom during the last year. Started with Microsoft's HoloLens, a bunch of similar devices have been released. Moreover, there was some development in niche areas such as gaze recognition, where new companies announced potential devices during the last year. Details are discussed in the following chapter.

3.1 Microsoft HoloLens

Figure 1: Microsoft HoloLens

The release of Microsoft's HoloLens is meanwhile already three years ago. Until recently, no serious competitor could claim to have a comparable mixed reality device. Therefore, Microsoft had no pressure to release a HoloLens update. During the last year the market situation changed, new competitors entered the market with the first serious mixed reality devices that are technically as advanced as the HoloLens. Consequently, Microsoft is preparing to release the second generation of HoloLens. A definitive release date has not been announced yet, but it is expected the update will be published early 2019.

The main improvements of HoloLens 2, codenamed "Sydney", are expected to affect the so far quite limited field of view, environment tracking technology, wearing comfort, more processing power, longer battery lifetime and a special Windows 10 version for improved Mixed Reality experience. While it is not clear how large the improved field of view will be, it has leaked that the new processor in the HoloLens will be Qualcomm's recently-announced XR1 chip.

3.2 Magic Leap One

Figure 2: Magic Leap One

The newest company offering a HoloLens competitor device is Magic Leap. The Magic Leap One headset is a pair of mixed reality smart glasses that has been hyped for several years already. A major difference between the Magic Leap One and Microsoft's HoloLens is the fact that the Magic Leap One is tethered. That means a cable connects the smart glasses to a small hip-mounted computer that handles the primary data and graphics processing. Moreover, the Magic Leap One does not directly accommodate people who wear corrective lenses. It can be especially fitted with the prescription lenses, but that would lead a user specific version of the glasses.

Magic Leap uses a 6 degree-of-freedom controller for interaction. In contrast to the HoloLens, Magic Leap offers additional eye-tracking for intuitive interaction going beyond gesture control. Finally, Magic Leap supports hand tracking with a basic set of 8 pre-defined gestures. In total, the device supports more different interaction technologies than any other smart glass currently on the market.

In terms of weight the Magic Leap One appears to be very comfortable to wear. Since the computing power is packed into the small pocket computer, the headset can be designed with approximately half the weight of the HoloLens.

According to the first reviews, the Magic Leap One is in overall a very promising mixed reality device. However, it is in its early stages, refinement will definitely be necessary in the future. Moreover, the focus currently seems to be very much on the consumer market, while real applications are of course not published yet since the device is currently only available as a developer version in the US. It will be interesting to monitor if the Magic Leap also will make a shift towards industrial use cases in the future.

3.3 Meta 2

Figure 3: Meta 2

The third mixed reality device that currently plays a serious role on the market is the Meta 2. While the first version of their smart glasses has been released already back in 2014 already, the update came at the end of 2017. In contrast to HoloLens and Magic Leap One, the Meta 2 requires a connection to a PC. It basically serves as a mixed reality screen for a PC. In scenarios where free navigation is required, this a major drawback. Currently, Meta 2 focusses on the concept of a mixed reality workspace where free walking is not required.

Interaction with the Meta 2 is accomplished by gestures similar to the HoloLens. However, the grab-and-hold gesture for example is reported to be less stable than the one known from HoloLens.

Compared to the HoloLens and Magic Leap One, the Meta 2 with about 90° offers the largest field-of-view of all three.

In total the Meta 2 still seems to be a prototype with many early features. For industrial applications it is currently not the appropriate device.

3.4 Daqri Smart Helmet

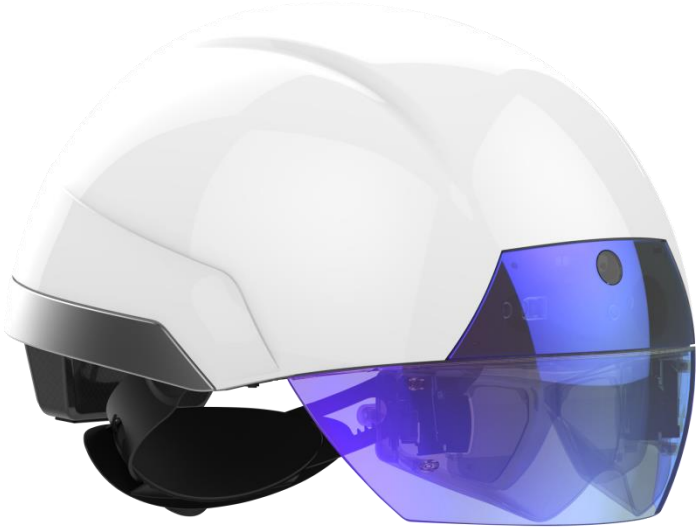

Figure 4: Daqri Smart Helmet

Daqri was working on its Smart Helmet for years, but withdrew it from the market last year. In future Daqri will focus on the Smart Glasses, basically the compact version of the Smart Helmet.

3.5 Intel Vaunt

Figure 5: Intel Vaunt

As the second discontinued device, Intel announced a pair of smart glasses last year but cancelled them again within a few months even before the first prototype was released. The focus of the Vaunt was not on mixed reality but rather on displaying basic contextual information in a very decent way. Therefore the device was rather planned to be in the category of a Google Glass instead of a HoloLens.

3.6 GlassUp F4

Figure 6: GlassUp F4

GlassUp is a pair of smart glasses obviously tailored for indutrial use. It features a monocular display in combination with a protetctive shield in front. Moreover, it is one of the rare smart glasses runnig a Linux OS.

3.7 ODG R-7HL, R-8 and R-9

Figure 7: ODG's smart glasses

ODG has been working on smart glasses for a while, starting with the R-7 a few years ago. Currently the ODG's portfolio offers three new smart glasses: R-7HL (the special edition of the R-7), R-8 and R-9.

For industrial applications the R-7HL (Hazardous Location) is interesting since it currently is the only smart glass that is tested and certified for extreme environments. It features various certifications such as ANSI Z87.1+ (Impact Eye Protection), ANSI Z87.1+ D3 (Splash Protection), ANSI Z87.1+ D4 (Dust Protection) as well as different Class I standards.

The R-8 and R-9 are equipped with improved hardware components such as faster processors, higher resolution cameras and larger field-of-view. However, they are not rugged devices as the R-7HL.

3.8 Viewpointsystem

Figure 8: Viewpointsystem smart glass

Viewpointsystem is a startup offering smart glasses with a special feature: eye tracking. By tracking the focus of the user with sensors, new ways of interacting as well as additional data as a source of information for collocated work scenarios become possible. The smart glasses are additionally featuring certified protective glass.

3.9 ThirdEye X1

Figure 9: ThirdEye X1

ThirdEye is a new company offering a pair of Augmented Reality smart glasses. The stereoscopic display offers a 40° field of view and the 2400 mAh battery should run for 6 to 7 hours. Equipped with a 13 Megapixel camera it can shoot images or video at up to 4K resolution. The X1 runs a modified version of Android that ThirdEye developed itself. Since the device is still in an early prototype phase, it is currently not clear if it will become a competitor for e.g. ODG smart glasses in the future.

3.10 Lenovo C220

Figure 10: Lenovo C220

Lenovo published their augmented reality smart glasses called C220 at CES 2018. The device is not yet available for customers. However, the technical specifications look interesting since Lenovo is targeting industry use cases with their smart glasses. The lightweight 60g glasses run on Android, feature a monocular display and an

adjustable 1080p camera. Moreover, it uses safety glass frames and bone conduction speakers (known from Google Glass).

Currently, the C220 runs tethered to an Android smart phone as main computing unit. According to the available specification, the Lenovo C220 smart glasses can recognize and identify real-life objects using AI technologies.

Since such a large company as Lenovo is working on the C220, it will be very interesting in the future to watch if these smart glasses will become a major player on the market.

3.11 Toshiba dynaEdge AR100 Smart Glasses

Figure 11: Toshiba dynaEdge AR100 Smart Glasses

Toshiba is also announcing a pair of smart glasses called dynaEdge AR100 Smart Glasses. It is basically a Vuzix M300 connected to Toshiba's dynaEdge DE 100 Mobile Mini PC. This is especially interesting, since the AR100 is based on one of the most popular smart glasses currently available but with the difference that it offers more computing power and runs on Windows. These two facts might be especially relevant for industrial use cases, since Windows is by far the most common OS in this area.

Toshiba is therefore taking a different approach compared to most other smart glasses companies nowadays. It is focussing on the dynaEdge as a mobile mini PC for the workplace with the smart glasses as possible but not mandatory extension.

As a summary, a table is introduced to compare the main features of the presented devices and with their corresponding TRLs.

							
	Name	Hololens	Meta2	Magic Leap One	Daqri Smart Glasses	GlassUp F4	ODG R-7HL
Features	**SDK**	Yes	Yes	Yes	Yes	Yes	Yes
	M/B	B	B	B	B	M	B
	Resolution	1280x720	2560 x 1440	1280×960	1360x768	640x480	1280 x 720
	Battery (h/ mAh)	2 / 3000 mAh	Tethered with PC	Up to 3 hours	5800 mAh	4000 mAh	1300 mAh
	Memory(GB)	64	Tethered with PC	128	64	16	64
	Speaker/Micro.	Y/Y (4)	Y/Y (4)	Y/Y	Y/Y (4)	n/a	Ear Buds / Y
	WiFi	Yes	Tethered with PC	Yes	Yes	Yes	Yes
	Bluetooth	4.1	Tethered with PC	Yes	4.0	Yes	4.1
	Weight (gr)	579	500	345	312	251	220
	Availability	Avialable	Prototype	Prototype	Prototype	Available	Available
TRL	**Consumer**	8	5	5	5	5	5
	Industrial	5	5	5	6	7	8

						
	Name	RealWare HMT-1	ThirdEye X1	Lenovo C220	Google Glass Enterprise	EPSON Movierio BT-2200
Features	**SDK**	Yes	Yes	Yes	Yes	Yes
	M/B	M	B	M	M	B
	Resolution	854x480	1280 x 720	800 x 480	640x360	960x540
	Battery (h/ mAh)	8 / 3250 mAh	2400 mAh	1700 mAh	1-2 / 780 mAh	4 / 2 x 1240 mAh
	Memory(GB)	16	32	32	32	8 / 32 (SD)
	Speaker/Micro.	Y/Y (4)	n/a	Yes / No	Y/Y	Y/Y
	WiFi	Yes	Yes	Yes	Yes	Yes
	Bluetooth	4.1	4.1	4.0	4.0	4.0
	Weight (gr)	370	285	60	60	290
	Availability	Avialable	Available	Prototype	Available	Available
TRL	**Consumer**	9	5	5	6	8
	Industrial	9	6	6	7	8
Overall	**Consumer**	**9**				
	Industrial	**9**				

4 Smart Watches

Compared to the smart glasses market, there was still no trend towards industrial devices visible within the area of smart watches during the last year. The main focus remains on consumer devices, since smart watches are meanwhile well established in this sector.

4.1 Workerbase

Figure 12: Workerbase Smartwatch

The only exception is Workerbase, a smartwatch directly aiming at industrial use. The Munich based Start-Up developed the first market-ready industrial smartwatch. Workerbase is inspired by the consumer market and combined the knowledge with the requirements from industry. The result is a smartwatch with a 320x240 touchscreen that integrates a 8 MP camera and a barcode scanner supporting use cases such as picking, step-by-step instructions or documentation. Moreover, the smartwatch supports NFC, WiFi and Bluetooth. It runs on Android 6.0. According to the company, the first large companies are running pilot tests with the WOrkerbase.

5 Conclusions

One of the greatest efforts during in these years has been the technological surveillance in augmented reality topics. The underlying reason is the fact that the Augmented Reality is one of the most promising technologies in the field of the factories of the future. As we know, these technologies are still at the previous phases of the Hype Cycle of Gartner [32], while other HCI enabling technologies are much more mature so they do not experience many improvements.

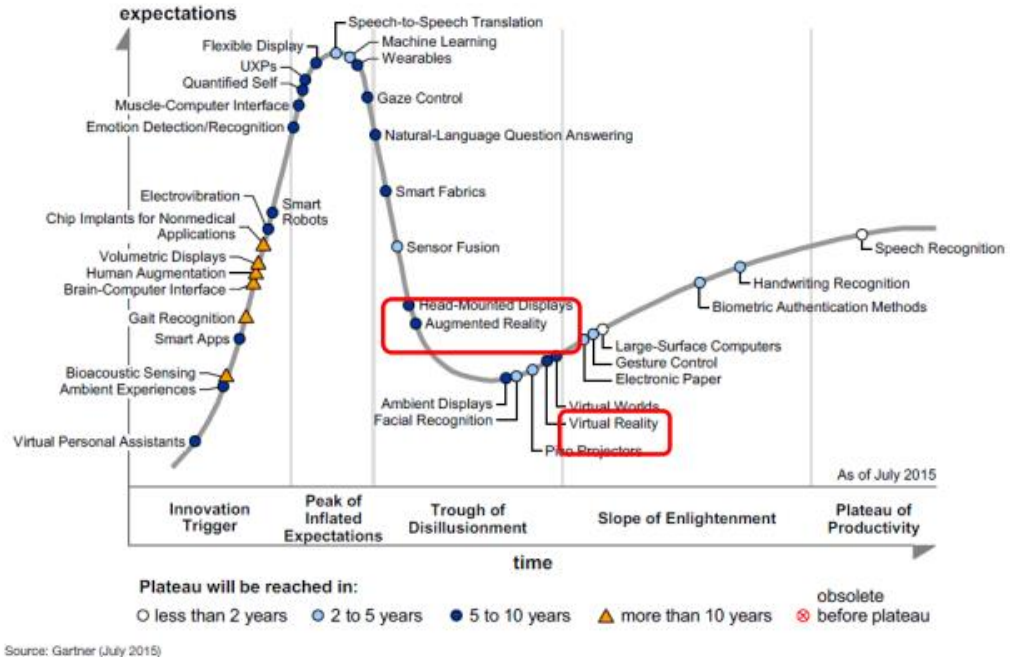

Figure 13.- 2015 Gatner Hyper-cycle.

Augmented Reality is expected to be a key technology in industry to achieve greater efficiency and improved productivity. The ability of AR headsets to provide visual overlays of complex instructions over workers tasks on physical structures on the shop floor is perceived as highly valued within the FACTS4WORKERS project and these features can benefit some of the planned use cases.

During the years of the project, an increase in the availability of head-worn devices (HMD) has been experienced. It has happened the same with platforms, SDKs and contents. However, the current technology is not ready for being integrated in the factories. It still lacks maturity and the adoption process is at a slow pace.

Regardless, we consider that in the coming years, field service workers, those who maintain utilities, infrastructure, machines and equipment, will benefit because their work is often 'hands-busy' tasks," so these workers could highly benefit from the

features of AR like overlaying information, images and diagrams; enable recording to foster collaboration (enable "see-what-I-see" context), etc.

For these reasons we have presented annual revisions of the devices and SDKs as we consider this technology will evolve from pilot projects that are being implemented today into a shop floor fully integrated technology which will help workers to perform their tasks in a more efficient and productive way.

These hardware and software revisions were performed during the four years of FACTS4WORKERS duration. Figure 14. summarizes the evolution of the technologies considered for supporting workers tasks on shop-floor.

When focusing on the HCI systems, it can be observed technologies for being used on industrial environments have a great evolution. Most of the wearable devices, cross platform SDKs and data visualization SDK gather a 9 TRL in our assessment. However, when we consider the AR systems, our evaluation of the TRL are still in 7 level for consumer and 6 level for industrial use. It is due the TRL level of tracking techniques, the capabilities of interaction and the available SDKs.

These evaluations are aligned with the feedback received from workers. Interested readers can take a look to FACTS4WORKERS final evaluation report (Lacueva et al., 2018). There in the use cases where AR and mixed reality solutions were used workers reported smart-glasses are quite heavy and they cannot be used comfortably when prescription glasses are too. However main issues were reported in relation with the interaction capabilities and the generation of content.

Workers requested better interaction capabilities with the shown 3D holograms. Probably these requirements are based on the numerous demos available on line promising the capability of interact independently with any of the parts on the view. Gathering this level of interaction requires a complex integration of the 3D models within the AR system. While it is possible it requires the participation of an expert (3D models, AR programming, etc.) in order to create the content. While it's requested by the workers, to introduce this profile on the factories, it is also requested to be able to create the contents by them.

Finally, by comparing our TRL level for AR systems and the expected achieve of the Plateau of Productivity of 2015 Gartner Hyper-cycle it can be say they are aligned at it is expected to be five to ten years and it is just four from our first reports. In any case workers highlighted AR can contribute to save time and money when it is used for training people.

HCI Technologies					TRL Assessment							
					2015		2016		2017		2018	
Level 1	Level 2	Level 3	Level 4	Level 5	Consumer	Industrial Shop Floor	Consumer	Industrial Shop Floor	Consumer	Industrial Shop Floor	Consumer	Industrial Shop Floor
HCI Single Technologies					6	5	6	5	7	5	7	5
	Conventional Technologies				6	5	6	6	7	6	7	6
		Text Entry			7	5	8	6	8	6	8	6
		Display Devices			7	5	7	5	7	5	7	5
		Screen Positioning, Pointing and Drawing Tech			6	5	6	5	8	5	8	5
		Printers			7	5	7	8	8	8	8	8
	Touch-sensitive Screens (Touchscreens)				9	5	9	7	9	7	9	7
	Image and Video Devices				9	7	9	7	9	7	9	7
		2D			9	9	9	9	9	9	9	9
		3D			9	6	9	6	9	6	9	6
	Computer Vision				6	4	6	4	6	4	6	4
		Recognition.			6	6	6	5	6	5	6	5
		Motion Analysis			6	4	6	4	6	4	6	4
		Scene Reconstruction			5	5	5	5	5	5	5	5
		Gesture Recognition, Behavioral or Gesture An			7	4	7	4	7	4	7	4
		Eye Tracking			7	3	7	3	7	3	7	3
	Audio Input/Output Technologies.				7	6	8	7	8	7	8	7
		Speech Recognition			7	6	7	8	8	8	8	8
		Text to Speech			9	6	9	7	8	7	8	7
	Context Awareness Technologies				4	4	5	4	5	4	5	4
		Positioning, Location and Identification Techn			7	5	7	5	7	5	7	5
		Qualified Self			5	5	5	5	5	5	5	5
		Emotion Detection, Affective Computing, Mood			4	4	4	4	4	4	4	4
	Haptic Interaction				9	9	9	9	9	9	9	9
	Brain Computer Interaction				3	2	3	2	3	2	3	2
HCI Systems					6	4	8	6	8	6	8	6
	Mobile Devices				9	7	9	7	9	7	9	7
		Mobile Devices			9	6	9	6	9	6	9	6
		Rugged Mobile Devices.			9	9	9	9	9	9	9	9
	Wearable User Interfaces.				5	4	7	6	7	7	7	7
		Smart Watches			7	5	9	7	9	7	9	9
		Smart Glasses			6	5	9	7	9	9	9	9
		Hearables			5	3	9	7	9	7	9	7
		Smart Clothing			3	3	3	3	3	3	3	3
		Nearables			9	9	9	9	9	9	9	9
	Cross Platform (CP) Software Environments				7	5	9	7	9	7	9	9
		Smart Opetating Systems.			9	5	9	5	9	5	9	9
		CP Development.			7	7	9	9	9	9	9	9
	Data Visualization				9	5	9	9	9	9	9	9
	Augmented Reality				5	4	6	5	6	5	7	6
		Augmented Reality Tracking Techniques			5	4	6	5	6	5	6	5
		Interaction Techniques and User Interfaces			5	4	6	5	6	5	6	5
		Augmented Reality Display Technologies			6	5	7	6	7	7	9	9
		Augmented Reality SDKs			5	5	7	5	7	6	7	7

Figure 14.- FACTS4WORKERS TRL taxonomy evaolution.

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ABOUT THE PROJECT

The high ambition of the project FACTS4WORKERS is to create Factories of the Future with a pervasive, networked information and communication technology that collects processes and presents large amounts of data. These smart factories will autonomously keep track of inventory, machine parameters, product quality and workforce activities. But at the same time, the worker will play the central role within the future form of production. The ambition of the project is to create »FACTories for WORKERS« (FACTS-4WORKERS), to strengthen human workforce on all levels from shop floor to management since it is the most skilled, flexible, sophisticated and productive asset of any production system and this way ensure a long-term competitiveness of manufacturing industry. Therefore a serious effort will be put into integrating already available IT enablers into a seamless and flexible Smart Factory infrastructure based on work-centric and data-driven technology building blocks.

These solutions will be developed according to the following four industrial challenges which are generalizable to manufacturing in general:

- Personalized augmented operator,
- Worked-centric rich-media knowledge sharing management,
- Self-learning manufacturing workplaces,
- In-situ mobile learning in the production.

PROJECT PARTNERS

The FACTS4WORKERS project is composed of 15 partners from 8 different European countries:

Virtual Vehicle Research Center	Austria
Hidria TC Tehnološki center d.o.o.	Slovenia
Universita degli Studi di Firenze, Department of industrial Engineering	Italy
Technische Universität Wien	Austria
ThyssenKrupp Steel Europe AG	Germany
Hidria Rotomatika d.o.o., Industrija Rotacijskih Sistemov	Slovenia
iMinds VZW	Belgium
Sieva d.o.o.	Slovenia
University of Zurich, Department of Informatics	Switzerland
Thermolympic S.L.	Spain
EMO-Orodjarna d.o.o.	Slovenia
Evolaris Next Level GmbH	Austria
Itainnova - Instituto Technologico de Aragon	Spain
Schaeffler Technologies AG & Co. KG	Germany
Lappeenranta University of Technology	Finland

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Technology Monitoring: Report on Information Needed For Workers in the Smart Factory

D2.4, Technology Monitoring: Report on information needed for the Industrial Challenges workers with taxonomy is part of the work in progress of FACTS4WORKERS. T2.1 is an activity of WP2 aiming to highlight the current state of the applicable technologies (both hardware and software) which can be used for implementing Worker Centred Industry 4.0 solutions, which are already applicable and under which risks.

D2.4 takes as base the previous three reports as base for determining if available AR technologies can be used of shop-floor for supporting workers task and, which are the limitations presented by them.

As it made D2.3, this report use the methodology defined in D2.1 and D2.2 for assessing the TRL of available technologies (software and hardware) in consumer environment and industrial environments. In addition, as mobile systems are mature enough for being used on shopfloor, D2.4 and D2.3 only focus on AR technologies as they are key-enablers of the Industry 4.0 vision.

D2.4 updates previous version of FACTS4WORKERS taxonomy of HCI technologies. The taxonomy is used for determining the current TRL of AR systems but also for presenting the evolution of the technologies during the last four years. This evolution is aligned with Gartner 2015 Hype-cycle and it is used for presenting the main risk and limitations of AR technologies. However, our conclusions are enriched with the comments from shop-floor workers which are gathered from them during the evaluations of the deployed prototypes. These comments and other more general about the introduction of Industry 4.0 worker centred solutions can be found in D6.3 and D6.4 available on FACTS4WORKERS web site.