OPERATOR 4.0 – APPROACH

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Contents

1. Preliminary clarification

1.1. Background

The fourth industrial revolution, called Industry 4.0, with the aim of a more comprehensive digitalisation of various sectors is already underway in many places. The focus is on networking machines and processes with the help of information and communication technologies in industry. Within the framework of this networking, there are many opportunities for companies to generate advantages over previous approaches with the help of new technologies and approaches. In addition to the digitalisation of production facilities, plants and their communication and networking with each other, we should not ignore the human factor. The rapid development of digitalisation and the constant miniaturisation of intelligent sensors and portable devices has created the possibility of developing intelligent aids and work areas for operators and thus allowing them to participate in the development. The 4Steps project will analyse these new possibilities and explore potential fields of application for the new wearables technologies.

1.2. Objectives

The aim of this report is to take a closer look and analyse initial concepts for the Operator 4.0 in today's industrial environment. The different types of intelligent workers, see Figure 1, will be evaluated for their applicability and economic benefit in the current industrial environment. For this purpose, the Operator 4.0 typology according to Romero will be used [1].

Figure 01: Operator 4.0 Typology according to Romero (Source: Romero)

2. Operator 4.0 approach

The following section identifies and describes the types of Operator 4.0 (see Figure 01) approach considered in this report [1]. These approaches of the "intelligent operator" consider different functions and technologies that could be used individually or in combination with each other. All of the types described are extensions of the worker's capabilities and possibilities for action with the aim of achieving improved performance, cost savings or more efficient work processes and thus further optimising them. In addition to use in production, production-related areas and interfaces are also taken into account.

2.1. Super-Strength Operator

Exoskeletons are wearable and flexible, but differ in weight and mobility depending on the design. They are a biomechanical component in which the human-robotic exoskeleton is driven by a system of motors, pneumatics, levers or hydraulics. A distinction can be made between two types of exoskeletons, passive and active systems. The former do not require any energy supply and function purely mechanically, for example with the help of spring or cable systems. For heavier lifting activities, however, the active variant is preferable. Although these require an additional energy supply, they benefit from other advantages and can enable the employee to apply additional force to the lifting activity. The exoskeleton should be guided or controlled by the operator to enable the movement of the limbs with increased strength and endurance. The idea of the wearable exoskeleton has been around for a long time, and various aids in the form of gripping arms and lifting aids are already being used in industry to increase the strength of humans for physical tasks [1].

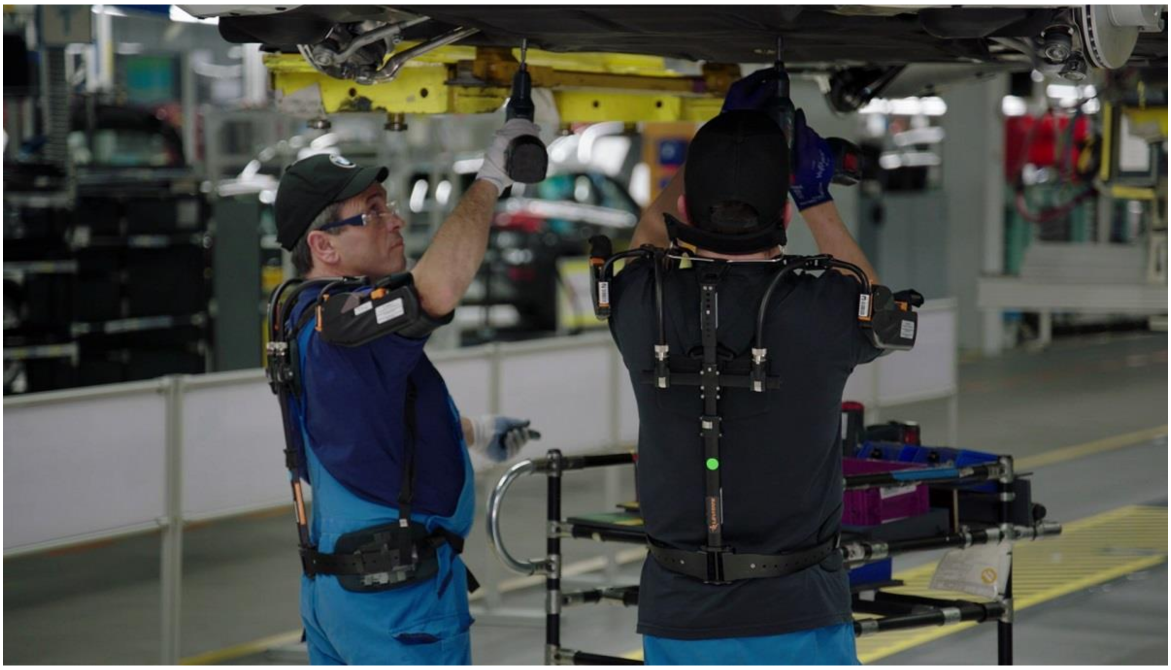

Figure 02: Exoskeleton in the production (Source: Media-Manufaktur GmbH)

The systems currently already in use mainly support the employee in performing the task and do not lead to a massive increase in the employee's strength. However, with a support of several kg per lifting operation, the systems reduce the physical strain of the employees during the performance of their tasks, fatigue symptoms and sickness-related absences can thus be reduced. By providing support during lifting movements, workplaces are made safer and easier. The degree of physical exertion required of employees when performing their tasks is reduced [1].

Figure 03: Exoskeleton to support lifting operations (Source: German Bionic)

2.2. Augmented Operator

Augmented reality (AR) is a technology that enriches the real environment with digital information and media (sound, video, graphics, GPS data, etc.). These are superimposed on the human field of vision with the help of headgear or glasses or via aids such as smartphones, tablets or AR projectors. Therefore, AR can be seen as a key technology to improve the transfer of information from the digital to the physical world of the intelligent worker [1].

AR technology can offer significant benefits such as reduced error rates and increased reliability, and the ability to assist and guide the operator with additional visualisations in manual work and assembly processes. Similar to other visualisations inspired by lean thinking and already established, the technology can be used as a digital assistance system to reduce human error and at the same time reduce printed work instructions and computer screens. It also supports the worker in finding information by retrieving the information required for the current activity or task, e.g. from documentation, and displaying it as required without this activity first having to be interpreted by a skilled worker. AR can enable "digital poka-yoke systems" for labour-intensive tasks, for example, leading to a reduction in errors, rework and redundant inspections. Through the information provided, error-proofing systems can be implemented to increase the efficiency of the work steps and, at the same time, the quality characteristics and required documentation can be checked or created at the end of the executed activity with the help of object-based tracking and target/actual comparisons. In addition, AR technology can represent a new human-machine interface for IT applications and systems. It is possible to display important information to the operator that is otherwise only available via terminals of production data acquisition systems of the networked manufacturing processes and machines on site during the execution of the activity. These help in decision-making and improve, among other things, partially and fully automated multi-machine concepts by displaying all relevant information to the employee at any location. This can take place at the machine level by integrating information from existing shop floor data collection systems or can be implemented with emerging Internet of Things (IoT) technologies for condition monitoring of equipment. In addition to production support, AR can also be used for production monitoring and quality control as well as for production planning with integration into ERP systems.

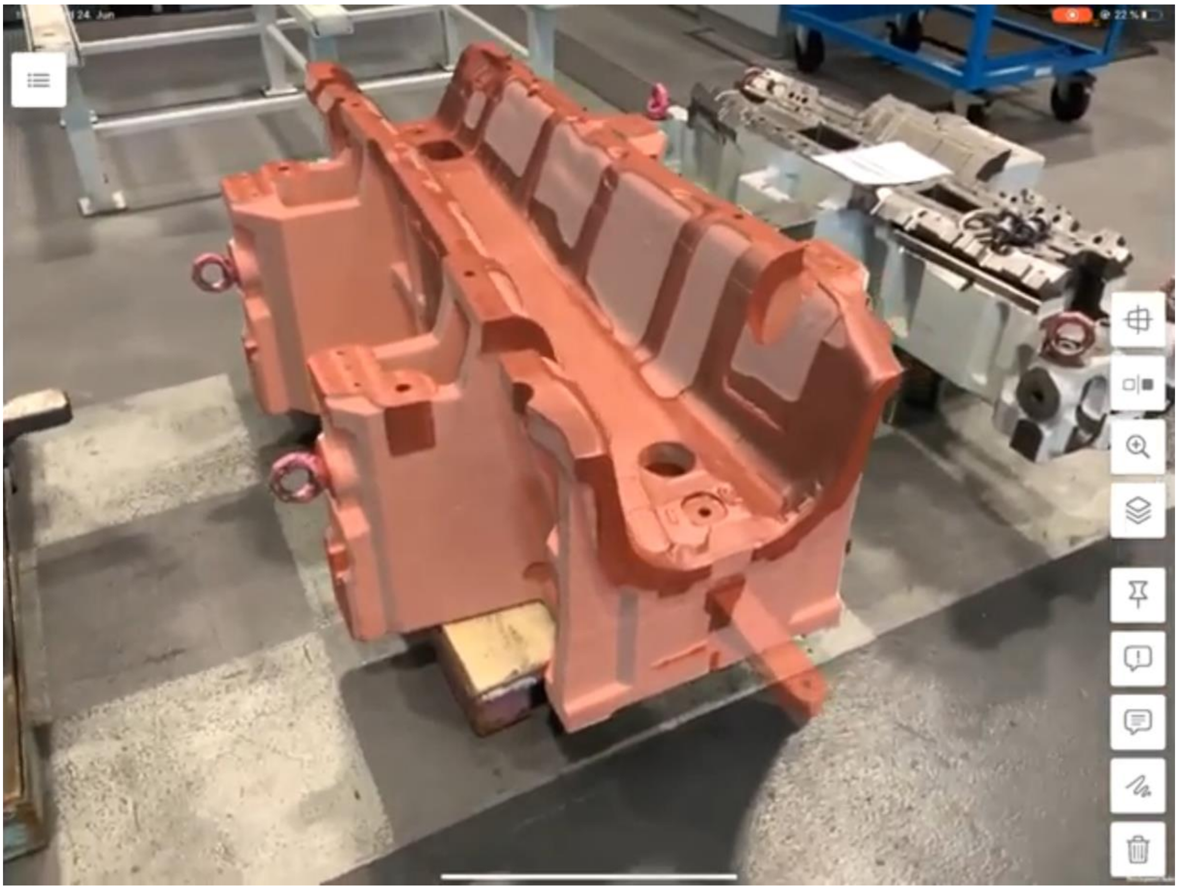

Figure 04: AR "Supar" application in use in toolmaking (Source: CDM-Tech)

2.3. Virtual Operator

Virtual Reality (VR) is an immersive and interactive computer simulated reality that can digitally recreate a construction, assembly or manufacturing environment. It allows the operator to interact with a digital twin, tool, product, robot or an entire production line with reduced risk. Through the networking of the plants and with the emerging fast and low-latency technologies, there will also be opportunities in the future for real-time transmission or display of ongoing production data in VR. This scenario opens up new possibilities for VR, so that the remote control of plants or robots is also conceivable in the future [1].

VR technology offers many advantages and potentials, e.g. it can combine a non-existent 3D scene with real objects to help in decision-making or training of the operator. For example, in the product design and planning phase, designs and conventional 3D models created during development or provided by suppliers can be converted into virtual 3D models and used for visualisation. These can be used in upstream design and planning decisions so that the design and possible changes and their effects can be checked along the product life cycle. This applies, for example, to manufacturability, assembly and disassembly, serviceability, maintainability, repair and reuse. The CAD models of products, individual parts, hand tools and assemblies can be converted into interactive models and used for virtual simulations (assembly sequences) or for training operators in complex assembly tasks. VR brings the "virtual factory" to life as an integrated simulation model and offers the possibility to evaluate important subsystems of a factory up to factory layouts, arrangements of machines, equipment and stock for a smooth flow of work and material. It also offers the possibility of virtual work scheduling, production line configurations, manufacturing process flows, process comparisons (automation vs. mechanisation) and production plans (work and capacity planning) to optimise the production plan by means of analyses, decision support systems and estimation methods [1].

Several specialised software solutions are now available on the market for the above-mentioned areas of application. In addition to the possibility of importing and displaying different 3D objects, these also include various tools for simulating required processes and interactions. This enables not only the design of a workplace but also the associated testing of ergonomics and aspects relevant to occupational safety. Necessary changes and optimisations can be made and evaluated without much effort. With the improved accessibility of the VR hardware and software, the technology also offers the possibility for workers, who were previously excluded from this process due to the complexity of the required software, to participate in the workplace design. This approach has already been successfully implemented through cardboard engineering / cardboard mo-deling, but it requires a lot of space and the creation of physical models out of cardboard. With VR, the basic idea is retained and both are eliminated, which is only one example of the potentials in R in the industrial environment.

Figure 05: Production planning with VR (Source: Halocline)

2.4. Healthy Operator

More and more portable devices are already being used in the private sector to record health-related data such as physical activity, heart rate, stress and other health data. For many, this offers interesting advantages in the private sphere; sporting activities and the performance achieved can be measured and adapted to one's own goals. Health abnormalities and deviations from the previously collected data can also warn the wearer and initiate important examinations. Collecting and evaluating these biometric data can also generate benefits in the professional environment. Planning, process specifications and employee statements can thus be evaluated and, if necessary, adjusted based on the data. With the evaluation and analysis, potentially problematic situations can also be predicted over time, so that appropriate measures can be initiated in good time. In addition, dangerous tasks and activities can be made safer by, for example, automatically switching off systems and live cables in the event of an electrical accident and calling for help. Here, smart textiles are increasingly being used which, in conjunction with other devices and wireless connections, also save the use of additional equipment and complex safety systems [1].

Figure 06: ANEGL - Smart Electrical Safety Assistent for emergency situations (Source: ADRESYS)

In a future production environment where the employee is no longer bound by company guidelines and fixed working time models, he could use this information and analysis to plan and set his work shifts. In addition, they could plan rest breaks and overtime based on health-related data and monitor their physical and cognitive workload during working hours and set warning limits to manage the right level of professional effort and stress.

The data or results of the evaluation could also be used for a personnel analysis in order to deploy the employees according to their abilities or to recognise increased workloads at an early stage and to inform the decision-makers. Through timely intervention and adjustments in the work process, the targets could be adapted to the employee's performance and potential errors could be prevented or minimised.

The aforementioned commercially available wearable solutions such as the Android Wear series or the Apple Watch devices are already being used by many people and are thus increasing the acceptance of such systems over time. However, the use of the devices in a professional environment and the evaluation of the data by the employer pose completely new challenges for data protection.

Figure 07: Smart Watch with health data (Source: Health Inside)

2.5. Smarter Operator

One of the main features of the smart worker is the support provided by an assistant. Such assistants are also already known from the private environment. With the products of the companies Apple, Google and Amazon, many have already been able to gain experience with personal assistants; they take over, for example, tasks of information retrieval with search functions and fall back on services of the manufacturers. In addition to the closed systems, however, Amazon's Alexa also offers an API, with this interface additional user-defined functions can use the device. However, these devices are currently not suitable for use in an industrial environment. In addition, they mainly work with the services and platforms of the manufacturers, which means that the issue of data protection has not yet been satisfactorily resolved for use in companies [1].

An Intelligent Personal Assistant (IPA) is a software assistant with online or offline connection that can take over certain tasks or services. With a voice-controlled interface, it enables the worker to request information and, if necessary, to have it displayed visually. This can increase productivity and efficiency by allowing the operator to perform certain tasks hands-free. It facilitates interaction with machines, computers, databases and other business information systems. Tasks where the operator has to interrupt the production process for documentation purposes or the service technician has to search for information in manuals can thus be taken over or provided by the assistant much faster and more efficiently [1].

Other scenarios in the professional environment where IPAs offer advantages are, for example:

- Searching and retrieving information from the shop floor recording or ERP system.
- Access to internal or external databases for information retrieval or the repair or maintenance manual of a machine or plant.
- The reading aloud or visual presentation of relevant information while the worker is performing the work.
- Documentation and notes
- Indoor navigation, positioning and picking in logistics
- Networking with machines and systems, automatic suggestions for troubleshooting
- Warnings and prediction models through trend tracking of monitoring systems of tools, machines or quality records
- Recommendations for preventive or proactive measures based on evaluation of information from the shop floor recording system

Figure 08: Smart Speaker, personal voice assistants (Source: Teltarif.de)

2.6. Collaborative Operator

A good example of this type of worker 4.0 is symbiotic human-robot collaboration, where manual and automated workplaces are combined. At least where batch size and flexibility allow and the cost-benefit analysis justifies the investment costs [1].

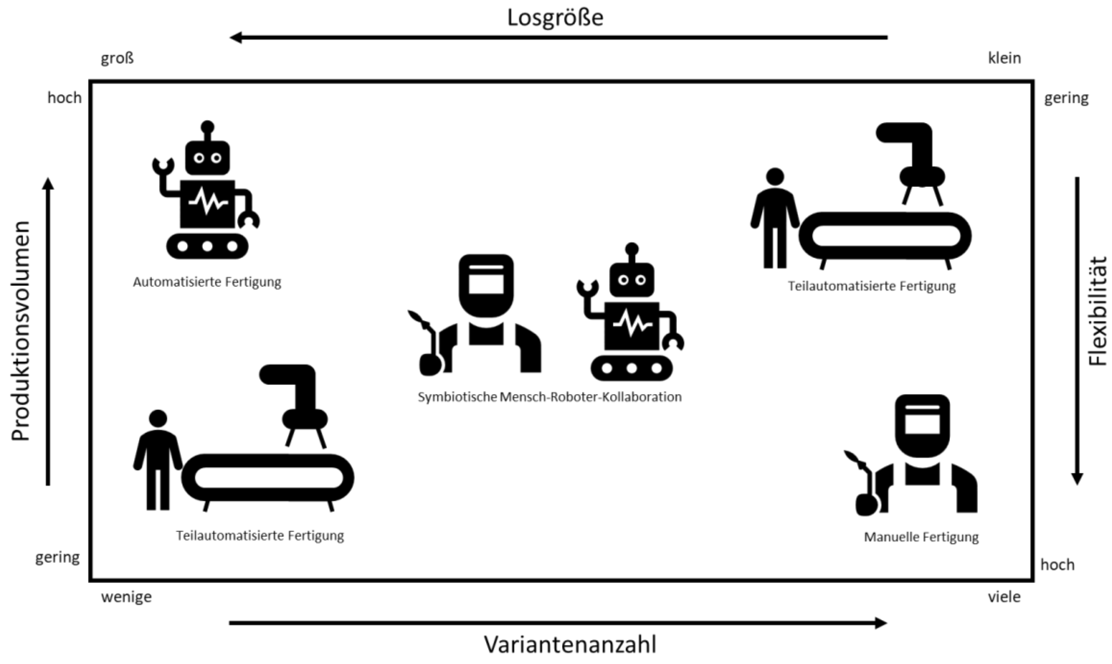

Figure 09: Production strategy (Source: (Heilala & Voho 2001, modified)

In contrast to partially automated work processes, the activities and work steps of the collaborative operator take place in a complementary manner. Robots specially built for these tasks, also known as cobots, are not intended to work exclusively autonomously and independently. They should interact with humans or be guided by them and, if necessary, also use the same workspace. Due to the desired interaction with the worker, these robots must enable new safety concepts so that the conventional safety barriers can be dispensed with. This will bring several advantages, including the reclamation of working space and the associated savings in the optimal design of the workshop or hall. But also the savings in the construction and implementation of such measures and the increase in productivity and satisfaction by assisting the worker or operator with tedious and non-ergonomic tasks. By providing the worker with an aid and thus support for non-ergonomic and dangerous tasks, including e.g. the difficult placement and assembly of components ("third-hand" functionality), heavy and repeated lifting and the handling of hazardous materials, not only efficiency and productivity increase, but also job satisfaction [2].

One of the main problems with the implementation of this idea, and one that severely limits the possibilities for implementation, is occupational safety. Due to different legislations, there can be differences in the distribution and use of such combinations depending on the country. Often it is not sufficient for the robot to have only one safety system and different safety measures are required. The regulations here can also depend on the application. For example, a distinction can be made between shared tasks and workspace, shared tasks and workspace and shared tasks and separate workspace. Despite the high potential, not all technically possible scenarios are currently implemented due to the aforementioned occupational safety requirements [2].

Figure 10: Robot control through motion transmission (Source: JAKA Cobot)

2.7. Social Operator

The social operator approach is primarily intended to connect employees with each other and in this way make the existing expert knowledge of all employees and workers available to everyone. There have already been initial approaches to this in the form of internal company forums and wikis with articles and contributions written by the employees themselves. The same applies to experiences and feedback from customers and work results that can be collected and evaluated in an internal database. Employees can access the collected knowledge via web interfaces of the intranet or directly during the execution of a task with the help of additional smart devices such as SmartGlass or AR glasses [1].

With the emergence of metaverse ideas, new possibilities arise for companies to make this information more easily accessible together with machine or sensor data. The new wearables technologies reduce the required equipment and enable the simple and portable retrieval of information. The employees do not have to call up the information before or after an upcoming activity, but can receive it directly on site. By integrating and merging the technologies with e.g. sensor data, internal location recording, object-based tracking systems, etc., the information can also be filtered automatically so that only the information relevant to the current activity or system is offered and displayed to the employee. The employee's location and movement data can be tracked with the help of wearables, e.g. via GPS data. Eye-tracking sensors make it possible to determine eye movements.

2.8. Analytical Operator

With Big Data analyses, the foundations can be created so that the employee receives support to optimise the production processes and faults can be foreseen in good time. Preventive measures and new processes can be derived from the collected and evaluated data, which help the employee to better understand existing processes and to further develop them in an optimised way. Together with operational data collection systems, the data from the areas of maintenance and repair can be stored and evaluated in a meaningful way. With the intranet and the new Metaverse approach, these can be made available to the social operator so that the analytical operator and the social operator merge and benefit from each other [1].

Figure 11: Production data acquisition system (Source: GrayMatter Software Services Inc)

3. Market overview

There are already different technologies on the market for the typologies mentioned. Depending on the technical status, these already cover partial areas or can already fully cover the application scenarios presented. With the emergence of new technologies and new networked approaches such as the metaverse, the already existing visualisation via transmission possibilities of information and data will be further optimised and adapted in the future. In the following, the already existing technologies and possibilities are presented.

3.1. Availability

3.1.1. Exoskeleton manufacturer

Table 1: Overview exoskeletons

Manufacturer / Supplier	Contact	Use Case	
		Industrial	Medical
Otto Bock SE & Co. KGaA	https://paexo.com	x	x
Hunic GmbH	https://hunic.com	x	
German Bionic Systems GMBH	https://www.germanbionic.com	x	
ReWalk Robotics Ltd.	https://rewalk.com/de/		x
Daiya Industry Co., Ltd.	https://en.daiyak.co.jp/en/company/aboutdaiya.html		x
ATOUN Inc.	https://atoun.co.jp/en/	x	x
Bionik Laboratories Corporation	https://www.bioniklabs.com		x
P&S Mechanics Co. Ltd.	http://walkbot.co.kr/?ckattempt=1		x
Focal Meditech BV	https://www.focalmeditech.nl		x
Hocoma AG	https://www.hocoma.com		x
Rex Bionics PLC	https://www.rexbionics.com/		x
Ekso Bionics Holdings, Inc.	https://eksobionics.com	x	x
Myomo Inc.	https://www.myomo.de		x
ATOUN	https://atoun.co.jp/en/	x	
C-Exoskeletons	http://www.exoskeletonrobot.cn	x	
Comau	https://www.comau.com/EN/MATE	x	
Crimson Dynamics	https://www.c-dyn.com	x	
CYBER HUMAN SYSTEMS	https://en.cyberhs.eu/	x	
Daiya Industry	http://www.daiyak.co.jp/product/categoryb/26	x	x
Ekso Bionics	https://eksobionics.com	x	x
Exomys	https://www.exomys.com	x	

FREE Bionics	http://www.freebionics.com.tw/en		x
German Bionic	https://www.germanbionic.com/en/home/	x	
Gogoa	http://gogoa.eu		x
Hexar Humancare	https://hexarhc.com/	x	x
hTRIUS GmbH	https://www.htrius.com	x	
Hyetone	https://www.hyetone.com/index.html	x	
Hyundai Motor Group	https://tech.hyundaimotorgroup.com/convergence/robotics/	x	x
ITURRI	https://exo.iturri.com/en/	x	
IUVO	https://www.iuvo.company	x	
Kubota	https://agriculture.kubota.co.jp/product/kanren/win-1/	x	
NUADA	https://nuada.pt	x	x
OCALIS	https://ocalis.com.tr	x	
RoboCT	http://www.roboct.com/en/home		x
Robosuits SRL	https://www.robosuits.it	x	

3.1.2. Data Glasses manufacturer

Table 2: Overview data glasses

Manufacturer / Supplier	Model name	Contact
Epson	Moverio BT-30C	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	Moverio BT-35E	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	MOVERIO BT-40S	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	Moverio BT-40	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	MOVERIO BT-35E	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	MOVERIO BT-300	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets

Epson	MOVERIO BT-350	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	MOVERIO PRO BT-2000	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Epson	MOVERIO PRO BT-2200	https://epson.com/moverio-smart-glasses-augmented-reality-devices-headsets
Picavi (Google)	Google Glass Enterprise Edition 2	https://picavi.com
IRISTICK	IRISTICK.H1	https://iristick.com/products/iristick-h1
IRISTICK	Visor-Ex®01	https://iristick.com/resources/visor-ex-01-smart-glasses-for-hazardous-areas
RealWear	RealWear HMT-1	https://www.realwear.com
RealWear	RealWear HMT-1Z1	https://www.realwear.com
Toshiba	DynaEdge AR100	https://asia.dynabook.com/smart-glasses/dynaedge-ar100/overview.php
Vuzix	M300	https://www.vuzix.com
Vuzix	M4000	https://www.vuzix.com
Vuzix	M400	https://www.vuzix.com
Vuzix	M400C	https://www.vuzix.com
Vuzix	Shield	https://www.vuzix.com
Vuzix	Blade	https://www.vuzix.com
Rochester Optical	Wearable Solutions	https://www.rochesteroptical.com/atheer/
Atheer	AiR Glasses	https://www.atheerair.com
Atheer	One	https://www.atheerair.com
Daqri	Smart Helmet	https://www.tworeality.com/en/virtual-headsets/daqri-smart-helmet/
GlassUp	eyeGlasses	https://www.glassup.com/en/
Magic Leap	Magic Leap 1	https://www.magicleap.com/en-us/magic-leap-1
Microsoft	Hololens 2	https://www.microsoft.com/de-de/hololens/buy
ODG	R7	http://www.motionwerx.com/odg-r7/
Optinvent	ORA-2	http://www.optinvent.com
Optinvent	ORA-EYE	http://www.optinvent.com
Optinvent	ORA-X	http://www.optinvent.com
Optinvent	ORA-EYE Remote Assistance	http://www.optinvent.com
Recon	Jet	https://wearables.com/products/recon-jet
SOLOS	Kopin	https://www.kopin.com/solos/

Toshiba	dynaEdge AR100 Viewer	https://www.xrtoday.com/augmented-reality/toshiba-dynaedge-ar100-review/
ThirdEye Gen	X2	https://www.thirdeyegen.com/x2-smart-glasses

3.1.3. Wearables

Table 3: Overview Wearables

Category	Manufacturer / Supplier	Model name	Contact
Funk-Ringscanner	Generalscan	GS-R1000BT 1D laser Bluetooth Ring Barcode scanner	https://www.barcodesinc.com/generalscan/
Funk-Ringscanner	Heroje	HJ21 Bluetooth Ring Barcode Scanner	https://www.heroje.cn
Funk-Ringscanner	PosTech	1D Bluetooth Wearable Ring-style Barcode Scanner UL-FS01	http://www.posunitech.com
Kabel-Ringscanner	socket mobile	Mobile Series 9 Wearable Ring Scanner	http://www.socketmobile.com
Kabel-Ringscanner	Honeywell	Dolphin 70e Black Wearable Mobile Computer	https://www.honeywellaidc.com
Kabel-Ringscanner	Zebra	RS419 Ring Scanner	https://www.zebra.com
Greifbox	CipherLab	Wireless-mini-Barcode-Scanner 1600	http://de.cipherlab.com
Faustscanner	Technology Solutions UK Ltd.	1062 Bluetooth HF RFID & Barcode Scanner RFID Reader	https://www.tsl.com
Faustscanner	Technology Solutions UK Ltd.	1153 Bluetooth® Wearable UHF RFID Reader	https://www.tsl.com
Handschuh-Systeme	PosTech	Bluetooth Barcode Scanner with glove MS3391	http://www.posunitech.com
Handschuh-Systeme	Riotec Co., Ltd.	Riotec DC-9260 1D MicroUSB Wearable barcode scanner for Android	http://www.riotec.com.tw
Handschuh-Systeme	ProGlove	Mark	https://www.proglove.com/de/
Kleidung (Shirt)	ADRESYS	Angel	https://www.adresys.com

3.2. Suitability for use

The exoskeletons, data glasses and wearables mentioned were specifically selected for use in the industrial environment, but are also used in part in the medical sector. There are many more wearables and assistance systems for private use, but these are not useful for industrial use or cannot be integrated into internal systems due to the issue of data protection.

The available exoskeletons offer both active and passive support for the employee. They are not yet in widespread use and their use is limited to activities in which full or partial automation cannot be sensibly implemented. These include initial approaches in the automotive industry (see Figure 2) or the use in manual activities that require a lot of effort, such as baggage handling in airports (see Figure 3). In most industrial work processes, gripping and lifting aids of various designs are already used to relieve the employee or to make the work process more efficient. In contrast to the flexibility of the employee, however, these are designed for a specific activity and are usually stationary. With a large variety of products and small batch sizes, these systems lack flexibility and individuality. An exoskeleton can remedy this by supporting the worker in manual activities and maintaining the flexibility for a quick production change. Despite the advantages that an exoskeleton already offers today, the areas of application are still limited and they are not preferred to known systems. With further development, new materials, greater mobility and more efficient energy consumption, this will change over the years and the use of exoskeletons can become established in further areas.

Augmented reality can be seen as a key technology for the worker 4.0. It has the potential to support the worker in different areas and can link different aspects with the new XR technologies. In areas close to production, AR using a tablet has already proven its worth and supports the worker in carrying out his or her activities. Here, maintenance and service applications, incoming goods inspections with target/actual comparisons, retrieval and display of information and quality inspections should be mentioned in particular. However, these systems are less suitable for use by workers in production because they have to be held and operated by hand. The emergence of new XR technologies in the form of AR glasses will change this in the next few years and with further developments in the areas of form factor, battery life and processor capacity, useful applications will also emerge in production. Promising approaches such as the display of process data and key figures from the production data acquisition systems or sensors and tool monitoring systems, visual poka-yoke solutions, situation-related retrieval and display of information, location-dependent visual displays when entering the plant or the workplace can be realised and lead to added value.

Virtual reality hardware and its application have not yet found their way into production. However, similar to augmented reality technologies, they can offer great advantages in production-related areas. The immersive visualisation of a digital twin and the possibility of 3D models in the preparation and planning of workplaces are good examples of efficient and cost-saving use of the technology. In the next few years, the further development of hardware will allow a fusion of VR and AR functionalities. This will open up new application possibilities and product-consumption-linked will also benefit from XR technologies. Due to new low-latency data transmission possibilities and the shift of processor power to external computing units, operable digital twins and multi-machine concepts may also represent a realistic application in the near future. Compared to AR glasses, the technical development in the field of virtual reality is more advanced and therefore currently offers more sensible use cases and is already more widespread.

The categories of the Analytical Operator, Social Operator, Smarter Operator and Healthy Operator offer great potential on the way to Operator 4.0. However, these approaches individually do currently not have sufficient advantages for use in a production environment. Developments in wearable AR hardware suggest that, with the exception of textiles and clothing which will continue to cover individual areas, these categories will merge and all the benefits will be available in one device. With the constant networking of information systems and the metaverse approach in companies, XR technologies in these areas will show their advantages in the design of workflows and processes and find their way into production.

4. Demonstrators at VDC

Various demonstrators have been set up at the Virtual Dimension Center Fellbach to show and test hardware, industrial applications and concepts. The demonstrators can be tried out in the VDC's premises by appointment. We offer the possibility to test them extensively with the support of a member of staff and, if required, also offer advice on a wide range of topics related to the Operator 4.0 and the new XR technologies.

4.1. AR Service (Tablet)

To demonstrate augmented reality service applications, maintenance and repair scenarios can be simulated on a milling machine with the help of a tablet. This augmented reality solution with the help of a tablet is already proven and can be used sensibly in the service area.

Figure 12: Demonstrator: Augmented Reality Tablet Service Application at VDC

4.2. AR use cases (tablet + HoloLens 2)

With the advent of new technologies for augmented reality, existing concepts can be further optimised. Wireless AR glasses such as the HoloLens 2 offer further advantages: in contrast to a tablet solution, the employee has his or her hands free and thus removes another barrier to the sensible use of augmented reality. In addition to conventional applications, new use cases can also be implemented. The following demonstrators can also be shown at the VDC.

- Quality inspection with tablet
- Incoming goods inspection with tablet
- Remote Work with HoloLens 2
- Medical application with HoloLens 2
- Training application with HoloLens 2

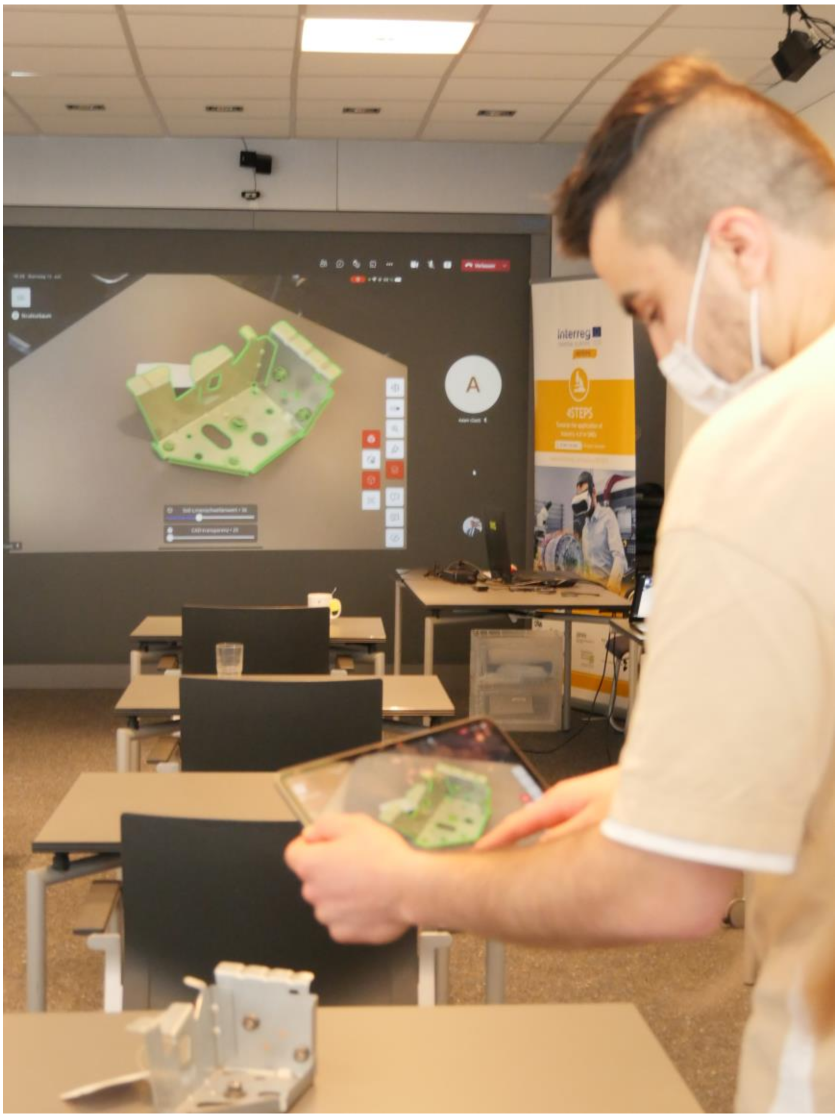

Figure 13: Demonstrator: Augmented Reality Tablet Quality Inspection at VDC

Figure 14: Demonstrator: Augmented Reality HoloLens 2 training application at VDC

4.3. Logistics smart glass (glasses + wearable scanner)

In some areas, the use of wearables has already become established and offers many advantages. This includes, for example, logistics and all activities where information has to be recorded and processed. At VDC we use a pair of data glasses, modified Google Glass 2 Enterprise Edition by Picavi, together with a Bluetooth scanner worn on the finger for a logistics demonstrator.

Figure 15: Demonstrator: Smart Glass and Wearable Logistics application at VDC

4.4. VR production planning

With the help of virtual reality, new ideas and concepts in production planning and process design can be easily implemented and made tangible. Planning that appears abstract can be spatially experienced and walked through. This makes the entire planning process more efficient, less error-prone and comprehensible for everyone. This can be demonstrated and experienced with different applications at VDC. For this purpose VDC has full versions of production planning applications that can be tried out with different hardware available at VDC.

- Layout planning
- Feasibility check
- Cardboard Engineering
- Workplace design
- Ergonomics Assessment
- Remote Collaboration
- Simulation and configuration

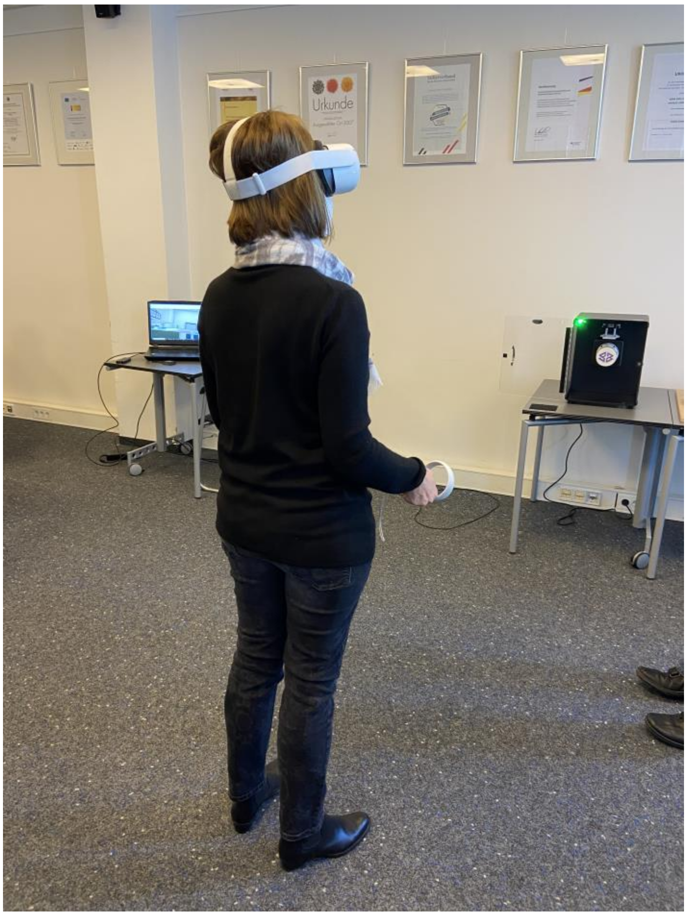

Figure 16: Demonstrator: Production Planning and Workplace Design Application at VDC

5. Conclusions, summaries

The existing and new XR technologies offer great potential to realise the future vision of Worker 4.0 in the industrial environment today. Even if this is not yet fully possible everywhere, individual aspects can already be sensibly implemented and lead to savings and more efficient work processes. Even if implementation in production-related areas is not yet fully possible, production-related areas can already increasingly benefit from the use of the technologies and approaches mentioned here.

It has been shown that exoskeletons can make tasks easier and reduce or even eliminate the use of additional tools. In addition, one benefits from less sick leave and the possibility to redesign workplaces ergonomically and differently. Activities that were previously not possible due to the weight limit for the activity to be performed can be realised with exoskeletons without additional tools or restrictions. However, this does not yet apply to all areas and production environments.

Data glasses and wearables can make visualisations easier and more accessible. It saves time for the preparation and follow-up of information, which means that the working hours of the employee in a shift can be replaced by direct value-adding activities. By connecting to shop floor recording systems and internal databases, information can be visualised in a more up-to-date way and, in some cases, in real time. The possibility to retrieve information on site saves additional walking distances and thus reduces interruptions and increases productivity.

A smart and lean production can be guaranteed and further optimised through a targeted selection of technologies and their integration into existing work processes. The technologies mentioned already help to further optimise work processes, influence further development and, when well integrated, can contribute to improving acceptance among employees on the way to Operator 4.0. However, further developments and improvements in the areas of form factor, battery life, ergonomics and range of functions are needed for widespread use.

6. References

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