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Potentials of Augmented Reality in Training

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Abstract

The technological advances through digitalization provide the basis for a new form of life. Targeting the future of work, digitalization will lead to a redesign of jobs, particularly in the manufacturing industry. This changes the requirements on employees, meaning new digital competences. To support employees building up the required competences different technologies such as augmented reality can be used. The aim of the study is to analyze the potential of augmented reality technologies to meet the outlined challenges. To fulfill this objective, this paper detects the potential of augmented reality as an innovative learning medium showing several use cases. It will be shown which different teaching and learning objectives can be achieved through the use of this technology in training with a special focus on practical learning scenarios in the industrial environment. This paper serves to optimize education and training in order to meet the requirements of digitalization more successfully.

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Keywords: Augmented Reality; Human Resources; Personal Development; Training

1. Introduction

The technological advances through digitalization in the area of cyber-physical systems, sensors or actuators enable maximum flexibility in all areas along the value chain. Different studies have shown that the increasing digitalization is affecting the society as well as the industry [4, 16]. In order to integrate digitalization in the company adjustments in all areas are necessary, from production up to human resources (HR). An aspiring technological trend in this context, is Augmented Reality (AR). AR devices are assigned to the group of digital supporting systems. Their use facilitates the work of the employees by providing data on-demand on a situation-specific basis and enriching real time situations with targeted information [14]. This enables to connect data with machines or work places without the need of a full

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computer workplace. The debate surrounding about changing processes by using new technologies, this also implies a change in the way people work. This is going to lead towards a redesign of the framework conditions as well as the work processes themselves, particularly in the manufacturing industry [17]. It is to be expected that work will become more flexible in different dimensions: local, temporal and content. Thus, there is unanimous agreement in theory, that interface competencies and the ability to solve abstract situational problems are gaining in significance [1, 4, 8, 16, 17]. It will be the task of education and training to take up the responsibilities of fulfilling these new requirements through innovative teaching and learning concepts. This raises the question of how far digital supporting systems, in particular AR technologies, not only improve the process itself, but can also be used as an innovative medium for practice-oriented learning.

Thus, this article refers on the potentials of AR in industry with a special focus on personal development respectively training. Therefore, after an analysis of the state of research, a three step methodical approach will be used to reflect AR as an innovative learning medium by examining several use cases. For this purpose, first of all the paper gives an introduction in AR with a focus on different teaching and learning objectives that can be achieved in internal and external training. Furthermore, the results of an AR potential analysis regarding training on the job (ToJ) and training near the job (TnJ) are presented. Afterwards, as a practical example, an industrial assembly process is analyzed, which is also outlined in the learning factory “smart production lab” at FH JOANNEUM. Finally, the conclusion comes up with some recommendations for companies that are planning to implement AR technologies for training. This practical example outlines, how training scenarios can be optimized in order to meet the requirements of digitalization more successfully.

2. State of research

AR describes the enrichment of reality through virtual elements such as information, objects, or interaction possibilities. Therefore, reality is superimposed or supplemented by relevant process data. Depending on the application, the information about the internal memory of the device, a network connection or a cloud solution is provided. The augmentation takes place depending on the technology used by means of overlay screens or sensors [12, 13, 14]. As a result, the various information can be provided from any location. It is possible to view, record and interact with information such as instructions, checklists, videos, podcasts or 3D-objects, use different (Android) apps with corresponding interaction options (from ERP systems to conference tools) or retrieve real-time data through interfaces to other software systems.

AR can be realized by different hardware, which are basically divided into wearable (e.g. smart phones and tablets) and non-wearable (e.g. smart watches or smart glasses) devices [13, 14]. Each device has individual hardware and software components and supports different areas of application. Comfort, environmental conditions and type of augmentation are just a few of the criteria that must be taken into account to make a selection which device is suitable for a particular application [7, 12, 14]. For example, only smart glasses, that are fully voice controlled enable hands-free working, which is ideal for training directly at the workplace. Using the device on the shop floor for instance, has increased demands on the robustness of the device such as shock-proof, dirt and water-repellent. Some industries even require explosion-proof equipment. In addition, the usability especially for workplaces on which devices cannot be deposited adequately, or gesture control is not possible due to the environmental conditions [6, 9, 13].

Due to this technical framework, AR provides various potentials for industry. It enables e.g. a permanent process acceleration or digitalized process monitoring in real time to parallel processes [11, 13, 17]. There are two types of processes that can be focused on: industrial processes as well as learning processes. If the focus is on the industrial processes themselves, it is possible to check which process steps can be improved by augmenting along the entire value chain. By providing information location-independent on demand, lead times can be shortened and non-value added activities can be reduced [3, 5, 11]. If the learning process is considered, AR devices represent an innovative learning media that enable new learning scenarios due to their technological possibilities. Thus, of particular interest is the use of AR technologies for Human Resource Development (HRD) to design further education and training in such a way that they are innovative and useful in the age of digitalization. HRD must provide rapid, on-demand, flexible education and training concepts to ensure the long-term agility of the company [15]. Looking at the learning objectives especially three areas of competences are relevant due to digitalization (see tab.1). *Training on the workflow* is relevant because of the increase of new technologies as well as the demand of flexible operational readiness of employees. *Decision making* and the *ability to solve sudden problems* effectively is no longer just relevant for decision-makers or service technicians but is also increasingly demanded by employees on the shop floor [11, 17]. Implementing AR technologies makes a contribution to meet these requirements especially in terms of ToJ as well as TnJ. Depending on the objective of the training, also different devices are suitable.

Table 1. Learning objectives due to digitalization.

Training of workflow	Training of decision making	Training of problem solving
• Ability to operate the machine and carry out processes • Shorter lead time of classical training • Step by step training of the workflow activities	Gaining additional knowledge about the process and the impact of own activities	• Rising the ability of solving standard errors • Understand quality factors in order to work preventive

Training on the job : ToJ means, that employees are gaining competence during their daily work. Therefore, it is no longer necessary to leave the workplace to look up something in the training documents, AR can provide the information right at the workplace [14]. As an example they can be trained step-by-step to a work process without causing serious damage [11]. This type of further training is also useful in order to bring employees back to less frequent process steps as needed [10, 14]. Furthermore, decision support applications can be made available to the employees, so that, for example, parameters to be entered can be checked for plausibility directly on site and indications of the effects of the decision can be given. This also trains employees in production in their decision-making competence and in the ability to think in a networked way [6]. This form of AR training is also called on demand training, which allows location-independent training attuned to the individual learning curve.

Training near the job: If intensive practice of activities is relevant, such as in the assembly or operation of machines where costly errors can occur, it makes sense to train near the job in a protected learning environment such as a seminar room or a learning factory using 3D objects [14]. However, the contents and tasks are directly related to the daily work and can be transferred into professional practice [15]. If a defined course of action or a specific interaction is to be trained in which both hands are needed, then non-wearables are not suitable for this purpose. Thus the aim of choosing the device must be to train as close as possible to the actual practical task in order to maximize the acquisition of competences.

Summing up it is not only important to define the intended use cases clearly before implementing an AR device. It is also recommended to conduct further applications to exploit the potential of this technology. Most scientific publications are focusing one AR solution, but the wealth of possibilities, especially in the field of training, are not shown at a glance. Also this paper is comparing one fully detailed assembly process and thus enables companies to check their own processes for AR potential in the field of further development. Therefore, the results also represent added value not only for literature but also for practice.

3. Methodology

The detection of AR potentials in training for a lean assembly and quality control line was the target of a project started at the institute of Industrial Management at FH JOANNEUM in 2017. The analysis was carried out by a group of students supervised by the corresponding author and was peer analyzed by the second author. Assembly of a cylinder with integrated quality control was chosen, since such activities are of great importance in almost all manufacturing companies. This process is fully represented in the smart production lab of the Institute Industrial Management and is used to teach students topics such as process optimization, automation or quality control in a practice-oriented way.

To detect the potential of AR in training for the outlined process, a three step model was conducted: At the first step, the detailed assembly process, was analyzed and visualized using the process management standard "Business

Process Model and Notation 2.0" (BPMN 2.0) [2]. A profound survey of potential can only be appropriately conducted if the process is transparent and documented and the employees have a basic understanding of them. For this purpose, process management in general and process analysis in particular provide a suitable methodology [2]. On this basis, in a second step, the potentials for the use of AR especially for training were raised, including a distinction between different types of AR hardware, depending on the environmental conditions. In the third step, a concept for the AR support was developed including possible learning objectives as well as methods to be integrated.

4. Results

Step 1: Process analysis

The outlined process includes four major sub-processes: *warehouse removal, piston assembly, piston rod assembly* and *cylinder assembly* that can be subdivided. It is triggered by a sales order recorded in the enterprise resource planning (ERP) system, in which the final product is defined more precisely. By exploding the bill of material, the required subcomponents are known, which have to be removed from the warehouse. Afterwards, they must be checked for the correct quality and replaced if necessary. Only if the quality is sufficient the assembly of the first cylinder part, the piston, can take place. A quality inspection completes the assembly part process. Afterwards, the second component of the cylinder, the piston rod, has to be mounted. Therefore, again different hands-on activities are needed. After successful assembly, the piston rod must be subjected to a concentricity test in order to be able to determine proper quality. Finally, piston and piston rod must be connected to a cylinder. Once this has been done, a leak test must be carried out before the finished cylinder can be transported to the finished goods warehouse. The result of the process analysis is a granular representation of all subtasks related to the assembly and quality control of a cylinder.

Step 2: AR potential analysis

The systematic potential analysis is carried out by clustering similar process steps into different activity types. Subsequently, characteristics for each activity type where defined. This was necessary to deduce adequate AR application areas. Table 2 shows the results for the outlined process.

Table 2. AR potential analysis of an assembly and quality control process.

Process steps	Activity types	Characteristic of the activity type
Check customer order, define final product and explode bill of material	Order breakdown	Handling real-time data, connection to the ERP system and location independent activity
Search storage bin of items, remove components and give faulty items to reject warehouse	Warehouse operations	Finding the right bin, lead the stock accounting and pick the right amount
Put lip ring on piston parts, connect piston parts with slip ring, put piston on test device, clamp piston rod, insert buffer piston, screw threaded piece, clamp piston in test device, assembly of cylinder, mount end cap, insert piston in bearing cap, fix position of bearing cap, equipping industrial screwdriver, tighten bearing cap and secure cylinder on tester	Assembly	Precise assembly procedure, repeating activity and manual activity
Control components, testing piston with a linear scanner, run concentricity test, assessment of correct mounting height and perform leak test	Quality control	Knowledge about suitable test methods, knowledge about quality-reducing factors and test accuracy
Decision on reject after stock removal, interpretation of linear scanner results, concentricity test results and result of leak test	Decision making	Overall process understanding, increased problem awareness, understanding the impact of the decision and assessment of the plausibility of the results

The left-hand column of table 2 shows the individual activities of the overall cylinder assembly process assigned according to similar tasks. For each bundle of tasks, a generalized cluster was defined, which is based on the objective of the activity. In accordance, different characteristics can be derived for each activity type. Those are the basis for the development of the AR training scenarios as they give information about the competences needed.

Step 3: Development of AR based training possibilities

If the requirements for the employees and the framework conditions of the individual clusters are known, AR training applications can be derived in the last step. The selection of hardware is based on a research of existing applications in practice as well as a comprehensive technology analysis, which was carried out within another project. The various device types available on the market were subjected to a utility analysis for use in producing companies. The result has shown that the dada goggle *hmt-1* from *realware* is particularly suitable for ToJ due to its hands-free approach and increased robustness. Tablets are a cost-effective alternative for working with 3D models. Due to the possibility and variety of individual software solutions no restriction on the software was made. Rather, it was worked out which use cases could be realized with the existing hardware. The selection of the right hardware is therefore just as important as the design of the learning arrangement itself. Table 3 gives an overview of the hardware requirements.

Table 3. AR based training arrangements.

suitable AR hardware	Requirements on the AR hardware
Order breakdown Tablet, Smartphone, Data goggles	• Interface capability to software systems • Data storage and/or connection to a network or the cloud • Processing of real-time data • Visualization of order data
Warehouse operations Smartphone, Smartwatch, Data goggles	• GPS tracking system • Interface capability to software systems • Space-saving
Assembly Data goggles	• Visualization of assembly instructions • Voice control / Hands free working • Robust hardware device if used directly on the shop floor • Compatibility with personal protective equipment if used directly on the shop floor
Quality control Tablet, Smartphone, Data goggles	• Visualization of test instructions • Assistance in carrying out quality control • Support in fault detection • Voice control / Hands free working • Robust hardware device • Compatibility with personal protective equipment
Decision making *Tablet, Smartphone, Data glasses*	• Interface capability to software systems • Data storage and/or connection to a network or the cloud • Processing of real-time data • Visualization of decision-making simulations • Support in the plausibility check with the help of comparative data • Visualization of the effects of the decisions

In the last step an attempt was made to describe AR training scenarios that could support the employees within the outlined assembly process. *Order breakdown* can be mainly trained by ToJ by either providing guided access to order management via interface or provider application to train the decision making process and increase awareness about the impact of one's own actions. It also supports the employees in their selforganization via optical signals when a new order arrives. *Warehouse operations* can also be trained directly on the job. For example, a control system could be set up to the correct storage locations (optically or via GPS tracking) including optical recognition and identification of the required parts (pick by vision) to train the individual responsibility. Also access to and capture in warehouse management via interface or provider application including real-time comparison of the number of removed parts with the required parts as per item could be provided to gain awareness about the impact of the individual tasks and support empowered employees by providing guidance and reference values. The *assembly* itself can be trained either near the job by visualizing virtual assembly orders through 3D modeling or on the job through providing assembly and safety instructions (using documents, step by step learning videos or color signals. When it comes to *quality control* TnJ could be provided by simulating different error types using 3D objects to train the error detection as well as the problem solving competences. At ToJ documents concerning test procedures including step-by-step instructions (for example as .pdf) or a glossary for quality reducing factors could be provided. Also on demand visualization of specification limits or display warnings regarding risk factors are conceivable to train the forward thinking ability of employees. At last, *decision making* should also be trained directly on the job using simulations of the impact of the decision with regard to other business processes or by providing an automated evaluation of the plausibility of the results.

5. Conclusion and recommendations

The use of AR solutions offers a multitude of potentials for industry. Path, set-up and process times can be shortened, employees can be individually trained and error rates reduced. Therefore, it must be distinguished between ToJ respectively on demand training methods and TnJ training practical frameworks in a protected training environment. Both forms of integrating AR technologies in training and further development lead to a significant reduction in costs. The present work using a standard assembly process, shows how training and further development can be improved by using AR technologies. It can be stated, that AR technologies represent an innovative learning media which enables flexible on demand training directly on the shop floor. Nevertheless, the results were subject to a limitation because they were derived purely from qualitative observations. A quantitative analysis, for example in form of a utility value analysis considering technical effort or costs, is recommended for the validation of the results. Still the analysis shows that a comprehensive potential analysis can only achieve the optimal result on the basis of a fully segmented process. To that end, the first recommendation states that companies should have transparent processes before considering an AR implementation. Furthermore, the analysis shows that when implementing AR devices, the objective and the expectations of the application must first be defined. This is because not every AR device available on the market can meet the requirements of the planned training scenario. On the one hand, the requirements are based on robustness and usability, on the other hand, on the technological possibilities (3D suitability, etc.). It is therefore recommended to companies to deal with the planned application areas and set out the frame before purchasing an AR device. Once the processes have been ascertained and the goals as well as the framework for AR has been defined, AR solutions can be implemented. It should be noted that the implementation of such new ways of training and working means a change for the employees, which is why a comprehensive employee integration in the implementation process of the AR solution is recommended. Only in this way a long-term successful implementation can be achieved.

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