Augmented Reality: Increasing Availability and Its Implication for SMEs

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Abstract The Augmented reality (**AR**) technologies have been first discovered in the third quarter of the twentieth century. However, the wider development of them has taken place only in the last two decades. By now, the research has shown that AR can be used in various areas of human activity. In industry, AR simplifies human-machine communication and improves human-machine interfaces (**HMI**) for fast and feedback-provided retrieval of training/guidance information for operation pattern study, error correction, machine maintenance, assembly assistance, etc. In spite of that, the broad practical implementation of AR in industry, including small and medium-sized enterprises (**SMEs**), has faced considerable problems. As a result, the following controversy emerged: the comprehensive study of AR is combined with a rather narrow practical use primarily for advertising and demonstration tasks. This chapter attempts not only to overview the current state of AR in the industry, but also demonstrate the current challenges the AR is facing, as well as to analyse their respective causes and suggest solution ideas. It is also intended to assess the prospects for further development of AR and its continued integration into the industry. For this purpose, several examples of AR projects, their development, practical use and upgrading (performed by the authors of this study as well) are presented.

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1 Introduction

Augmented reality (**AR**) is an interactive experience of a real-world environment that involves overlaying computer-generated visual, auditory, or other sensory information onto the real world in order to enhance it. Augmented reality offers the possibility to highlight real-world features, visualize information for audio features, relevant or expert knowledge (Ciupe et al., 2020; Glover & Linowes, 2019).

Nowadays, implementing AR is mostly a matter of software, as the hardware technology is already commercially available. There are numerous examples of AR usage in a large variety of areas (Cranmer et al., 2020; Yeung et al., 2021; Rosales et al., 2021). There is an established ecosystem of AR application development environments that creators can access (Glover & Linowes, 2019). AR is already available on more than 700 million devices with the arrival of ARKit and ARCore, not to mention third-party apps, and lastly, a considerable number of users have already used some form of AR, supporting the consumer readiness (Lizano, 2019).

However, the level of the integration of such technology seems to be hugely limited in terms of applications related to real-time production (Jalo et al., 2021). This chapter is aimed at the detailed study of the controversy between the respective issue and the evident advantages of AR for the small and medium size enterprises (**SMEs**), the maturity and widespread approval of it according to the formal metrics (Gartner Hype Cycle) and high consumer interest. The work is also going to present the possible causes of the phenomenon mentioned above, as well as support the discussion with relevant examples and the suggestions for future work in the overviewed research area.

2 AR in SMEs—Benefits

There are various reasons why an SME could profit from the use of AR technology. Cost reduction is one of the major advantages enabled by a mobile collaborative AR technology or any similar concept introduced into the production process. Cost reduction primarily derives from the reduction of traveling time and expenses for deploying, instructing, and supporting field service technicians, trainers, specialists, and other business-related staff (Anshari & Almunawar, 2021; Bottani & Vignali, 2019). Another major, non-production-related benefit of AR is the use of the technology in marketing, advertisement, and customer communication, increasing the overall consumer satisfaction, withstanding competitive pressure, and broadening the sales network (Chaffey, 2016; Masood & Egger, 2019). Moreover, AR can be used to relay essential information directly to the user considering any action happening in his/her closest environment. As a result, it leads to reducing the time spent by engineers, technicians, or maintenance staff referring to manuals, thus diminishing the service time, number of human-injected critical and acute errors, and the pressure on service employees (Bilous et al., 2022).

Despite seemingly offering a considerable spectrum of profitable features to the SMEs, the AR technologies still experience a lack of integration into the real industrial processes. There are many methods to represent the maturity, adoption, and social application of specific technologies, for example a so-called method of technology readiness levels (**TRLs**) (Héder, 2017). However, the implementation of a new technology in industry requires more than just technical assessment. For example, the economic and promotional components are essential. That is why comprehensive evaluation methods are required to assess the AR technology from this particular perspective. One of the most popular evaluation patterns is the so-called Gartner Hype Cycle (**GHC**) developed and patented by Gartner, Inc (Steinert & Leifer, 2010). According to this evaluation method, there are five key phases of a technology's life cycle, which represent the complex state of the technology and the attitudes of developers, investors and the public towards it.

Concerning the GHC results for AR, it rapidly reached a state of maturity, much earlier than experts expected. Steadily climbing up the GHC in the last years, AR slid down in 2018, and in 2019 it was not considered anymore an "emerging" technology (Bit, 2019; Herdina, 2020), but it had graduated as a mature one. The GHC did not include AR after 2020. This means AR has theoretically reached maturity and became an industry-proofed technology that can be safely invested into. However, the theoretical possibility of broad implementation of AR in the industry, in particular in SMEs, is still poorly realised in practice (Jalo et al., 2021; Anshari & Almunawar, 2021). This is highlighted by a number of problems and challenges concerning AR technologies and their wide implementation in industry, which have already been reported (Jalo et al., 2021; Anshari & Almunawar, 2021; Bilous et al., 2022; Berger et al., 2016). This issues are described and structured in the following section.

3 AR Implementation—Current Problems and Challenges

One of the main problems with AR technologies is the complexity of the field, which includes more than just software and hardware, but rather an extended spectrum of the scientific, industrial, and social aspects (Glover & Linowes, 2019; Jalo et al., 2021). In contrast, AR is widely regarded as only an overlay of the virtual information over the real world, therefore, seemingly completely excluding the knowledge background (Ciupe et al., 2020). The practical applications show that this assessment is true for simple training and demonstration tasks. However, once AR goes beyond these boundaries, the technology experiences the following challenges.

Implementation and adaptation issues. An innovative organizational culture is required for the development and for the adaptation of AR products in the SME industrial processes (Jalo et al., 2021). Furthermore, testing and integration of AR applications into the industrial environment of companies requires the flexibility of staff and their willingness to continuously exchange work experience (Jalo et al., 2021; Bottani & Vignali, 2019). At the same time, AR research continues apace and,

consequently, requires constant tracking of new development examples, projects and concepts in the field. Therefore, the demand for constant communication within the developer community is rising (Jalo et al., 2021; Glover & Linowes, 2019).

Technical (hardware and software) problems. The problem of data transfer between industrial environment (for example, programmable logic controllers, **PLCs**) and AR hardware is getting even more complex if the solution has to be scalable, i.e., effective not only for one unit, but also for several ones (Berger et al., 2016; Bilous et al., 2022). Moreover, the problem of User Activity Indication (two-way communication between personal and industrial environment) requires the ability to identify each user interaction with the industrial plant. A large number of additional sensors is required as a result (Bilous et al., 2022). Importantly, in the automation industry, new plants (an alteration in the overall construction, number and quantity of components, adjusted plant part positioning, etc.) appear to make a visible difference in the maintenance, operation process, and development environment. The creation of an application for a novel unit tends to become a task "from scratch" considerably fast. However, not many articles are dedicated to solving this problem now (Um et al., 2018).

4 Examples

Assembly, Repair and Maintenance. The introduction of AR into the field of maintenance tends to improve the process safety, reduces operator/assembly worker confusion, and withdraws the extra pressure from engineers to require expert knowledge in a wide variety of technologies and infrastructures. An example of using the AR assistant for assembly of plants' components is shown on the Fig. 1. It should be noted that the usage of AR as an assistant system for the assembly, repair and maintenance tasks is currently implemented in mostly large companies. For example, DIOTA has developed such a system for Rolls-Royce (Ababsa, 2020), which uses an AR application to assist the maintenance of jet engines.

In assembly tasks, AR technologies provide more reduction of human error rates rather than shortening of completion times. A good related example is presented in the work of Uva et al. (2018). The results outlined the improvement of the operators' performance in a seven-task maintenance procedure on a motorbike with respect to the paper manual study as a control group case, and the level of user acceptance of the new concept showed a certain increase.

In the context of the project **RepAIreality**, some of the authors of this study are currently implementing an AR-powered assistance solution for railway carriage technical management with their project partner Zedas. The proposed solution is meant to support workers while they are doing maintenance or repair work on railway carriages. To achieve this, important information is being presented to them via either a tablet or smart glasses. Using this approach together with digital work instructions, inexperienced workers can be enabled to perform the tasks that they are not yet

familiar with faster (Koteleva et al., 2021). It would also be conceivable to develop an adjusted version for other kinds of repair or maintenance work, so that a greater number of SMEs could profit from the presented AR approach.

Improving Human–Machine Interaction and Error Correction. To illustrate the practical use of augmented reality in an industrial environment with the goal of improved machine-human interaction, the chair of Automation of Brandenburg Technical University of Cottbus - Senftenberg developed a model of a laboratory facility to showcase the usage of AR in machinery debugging and correcting errors by non-expert users (Fig. 2) (Bilous et al., 2022).

The developed AR application was tested on a large user number (more than 100 respondents for the first version of the application and 30 respondents for the second version), and the experimental results showed that 100% of testers were able to fulfil the service requirements in the laboratory unit for the first time in an error situation.

User Manual. In 2015, Hyundai became the first mainstream car manufacturer to introduce AR user manuals (Halim, 2018). Consumers received instructions for repair, maintenance, and vehicle equipment guidelines via their smartphones or tablets.

The example of Hyundai seems to have demonstrated that inexperienced individuals are able to exploit the AR overlays with step-by-step instructions to identify problems and perform machinery repair without expert assistance. It should be noted that such user ability is also important for SMEs, as far as it greatly reduces the work of the customer support department, increases customer satisfaction and may profitably influence the future product purchase.

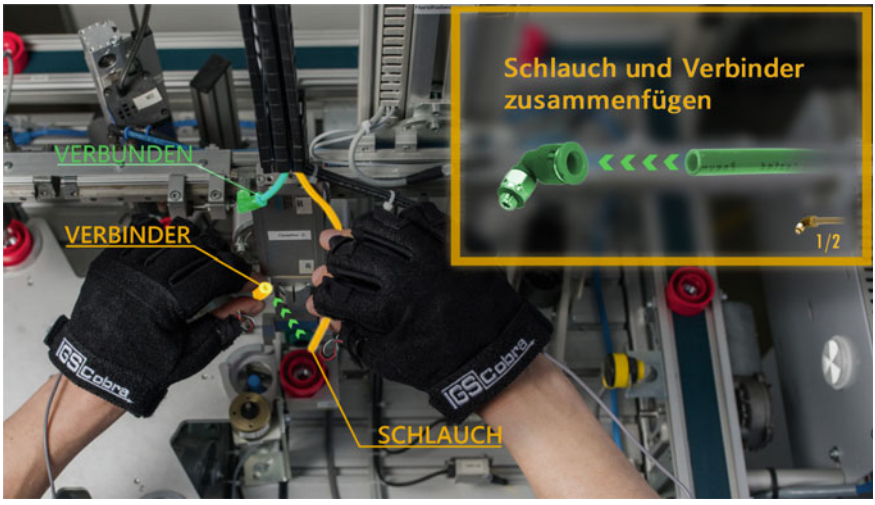

Fig. 1 Example of using the AR assistant for assembly of the plants' components

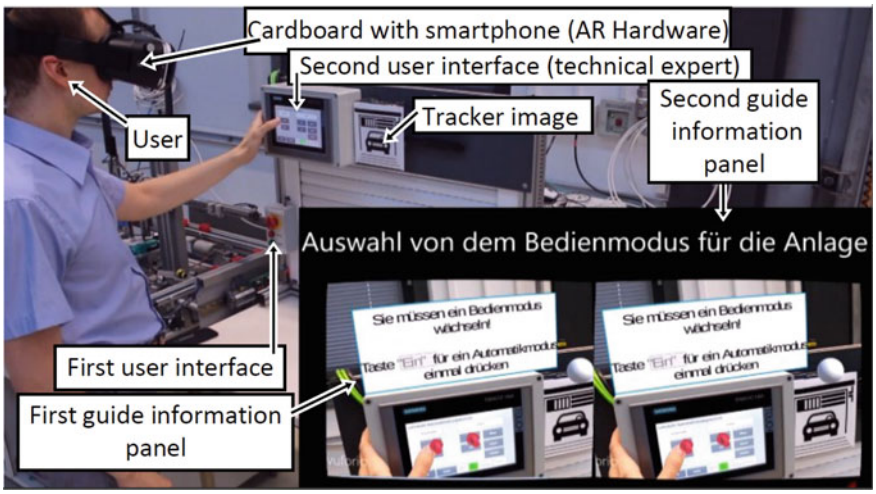

Fig. 2 Laboratory unit (small doors) and all AR elements (Bilous et al., 2022)

Marketing and advertisement. Considering this particular field, SMEs might clearly take advantage of the AR technologies to create unique user experience and strengthen the own brand. Regarding the currently available research and industry examples in this field, the company Theia Interactive has recently created the AR app to provide a virtual shopping experience that allows customers to experiment with different shapes, seats, lights and other options to achieve a truly custom bike design (Bosset, 2018). It should be noted that such customer AR applications are quite easy to develop, since they do not require active data exchange with, for example, laboratory units or industrial plants. The authors of the current chapter suggest that the combination of easy creation process support and captivating demonstration effects tends to make the increase of AR technology usage in this area particularly attractive to SMEs.

5 Conclusion

The further development of AR and the introduction of AR technologies in the field of SMEs appears to be prominent in the following categories:

Hardware. The solutions available on the market are already adequate to launch rather large (in terms of hardware requirements) AR applications. If the demand for the AR does not decrease, it is logical to expect a gradual reduction in the price of technical support devices. At the same time, a radical change in the design of AR hardware might not be the primary idea to expect in the next ten to fifteen years.

Software. The further development of modular solutions may be applicable in this field, both regarding commercial and freeware areas. It is possible that semi-automated and automated AR application generation projects will be started, but the authors of this article, based on their experience and analysis of current projects, anticipate that such projects will be purely scientific for a relatively long time.

Implementation and modifications of the AR applications. If the interest in AR for SMEs remains sufficiently high for a prolonged period of time, the community of both AR application developers and firms creating environments for their development/template packages for these environments will possibly expand. Nowadays, this has been already observed in physical engines. In this way, one can hope to create a similar database for new AR applications with the necessary AR element templates, program scripts, etc. Further progress in this direction may allow to build new AR applications literally in hours.

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