Implementation of Augmented Reality in Manufacturing: A Case Study Exercise

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Abstract Many companies are facing challenges implementing AR in various disciplines, including manufacturing. Against this background, there is a high demand to learn about major obstacles that come up during the implementation of AR in manufacturing, and to discuss strategies how to overcome those barriers. This current case study exercise resulted from an AREA-funded research project in collaboration with the xreality lab at the Bundeswehr University Munich. It presents a realistic situation of a fictitious yachting company that is confronted with multiple obstacles that come up with the implementation of AR in manufacturing. Trainers and educators can apply this case study. Participants of the case study should understand the challenges of implementing AR and discuss ideas of how to deal with these situations in real-life. Multiple approaches can be used to find answers to the proposed questions, such as (1) group discussions, (2) research in academic and industry publications (such as thearea.org blog), and/or (3) interviews or discussions with experts.

Keywords Augmented Reality · Manufacturing · Obstacles · Case study · Exercise · Training · Education

1 Augmented Reality: Revolution in Manufacturing?

Immersive technology and Mixed, Virtual and Augmented Reality are all terms that have analysts and industry visionaries excited, predicting that billions will be spent in the coming years. Virtual and Augmented Reality alone are forecast by IDC to grow to $162 billion in revenue by 2020. Especially Augmented Reality (AR)

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has the potential to become a disruptive technology in multiple disciplines such as marketing, education, innovation management, medicine, human resources, logistics, and manufacturing.

While the use for AR is wide-ranging, AR is generally defined as the enhancement of the real world by overlaying and realistically integrating computer-generated, virtual content into the environment (Jung, Chung, & Leue, 2015). A popular example of AR for the mass market is the 'Pokémon Go' app, which allows users to catch virtual creatures located in the real world (Rauschnabel, Rossmann, & tom Dieck, 2017). AR is typically considered as a medium that can be used on different devices, ranging from stationary over mobile devices (e.g. smartphones or tablets) to innovative AR specific wearables (e.g. smart glasses or smart contact lenses). In the near future, AR smart glasses are probably the breakthrough technology since they can be used hands-free (Rauschnabel, 2018).

For companies, AR can provide value in three ways (for a discussion, see Ro, Brem, & Rauschnabel, 2018): First, by developing new business models, where companies are entirely based on AR technology (e.g., Smink, Frowijn, van Reijmersdal, van Noort, & Neijens, 2019; Hilken et al., 2018). Second, by applying AR to reach customers, a concept termed "Augmented Reality Marketing" (Rauschnabel, Felix, & Hinsch, 2019). Third, by applying AR to execute existing tasks more effectively and/or more efficiently. One sector where actual performance, efficiency and bottom-line improvements are already being made is Enterprise Augmented Reality. Especially manufacturing is an emerging area of AR applications. Due to its complex internal processes and increasing globalization of supply chains, manufacturing companies need to access and exchange real-time information at different stages of the product lifecycle, i.e., design, prototyping, production, assembly, maintenance, and repair. Thus, AR technology is highly relevant in manufacturing by enabling users to simulate, assist and improve processes before they are actually carried out (Ong, Yuan, & Nee, 2008) and researchers argue that mobile AR applications will revolutionize the manufacturing industry in the future (Carmigniani et al., 2011).

While we observe an increased diffusion of AR solutions in manufacturing today due to enhanced AR software provision and the widespread use of hardware devices that are able to support AR applications (i.e. mainly smartphones and tablets), firms still face substantial challenges regarding a successful implementation of this innovative technology (Bottani & Vignali, 2019). Following prior research (Hein & Rauschnabel, 2016), we argue that the acceptance of AR technologies in manufacturing is relevant on two levels: On a corporate level, i.e. where top managers make and justify the decision to implement AR technology, typically based on strategic, legal and financial criteria. The second level is the user-level, where workers need to accept, adopt, and use AR technology. This is a particularly crucial level since the correct and intrinsically-driven use of AR is a crucial success factor to AR-efficiency.

The following case study has been developed as part of a collaborative research project between the Augmented Reality for Enterprise Alliance (AREA; thearea.org) and Universität der Bundeswehr München. It describes challenges of DreamerBoats Inc., a fictitious yachting company that is in the process of implementing AR in

their manufacturing. Readers are encouraged to discuss ideas and strategies of how DreamerBoats can overcome these challenges.

2 Case Company: DreamerBoats Inc.

DreamerBoats is a world-leading company in the yacht business. Its position and long heritage are a great source of pride, but they are even more proud of their people. Every member of the expert team is committed to providing their clients with the highest quality products and services in a highly transparent and reliable fashion. Members of DreamerBoats' 150-strong team are enthusiastic, empowered by deep knowledge and inspired to think innovatively in order to achieve consistent excellence. Supported by a range of effective IT solutions, they bring unquestionable trust to the experience of owning, chartering, selling, crewing and building a yacht. In the yacht building process, DreamerBoats guides its clients through every stage of the building process. The company also provides clear and transparent reporting on a regular basis so that clients are kept informed every step of the way. During the planning stage the project manager works closely with the client to ensure that all of the requirements are carefully set out and budgets and timelines are realistic. Based upon the requirements and using in-depth knowledge of bidding processes and construction methods, three dimensional drawings are developed in a CAD program. During the construction process, DreamerBoats combines standardized processes with many customized elements in order to fulfil each client's individual desires and remain in budget and on time. The project manager pays regular visits to the yard throughout the building and outfitting of the yacht. Sea trials verify that the yacht is operating properly. Any issues are quickly identified and resolved. After the delivery, DreamerBoats remains on hand to manage all warranty items with the shipyard.

Since building a yacht is an extremely complex business, involving many parties and a substantial investment in order to deliver the highly individualized product, the team at DreamerBoats is always looking for innovative technologies that support their work. A small innovation team leads the introduction of Augmented Reality (AR) technology into DreamerBoats' production processes. Using wearable AR devices, the team studied the use of AR in the four phases of yacht building.

3 Use Cases and KPIs for AR in Yacht Building

3.1 Preparatory Work

Using AR-assisted visualization of models permits early and low-cost "virtual build" reviews during the design cycle. Engineers, designers, quality control professionals and clients are able to assemble, test and diagnose the construction plan prior to

fabrication. Moreover, the manufacturer can digitally introduce the future yacht into the shipyard in order to review clearances for materials and tradespeople.

3.2 Work Instructions

Workers wearing AR displays will receive accurate and real-time work instructions in context with the tasks they are performing. If and when necessary, they will be able to receive assistance from a remote expert. If there are any changes to the standard operating procedures, these will be rapidly and centrally updated via technical publication systems.

3.3 Customization/Sign Off

During the assembly process, there may be decision points inserted at which time the craftsperson is able to offer customized variations. Examination of the progress with the client can be performed on site or remotely, and with contracting authority thus reducing delays when working on highly customized parts.

3.4 Intermediate and Finale Inspection/Documentation

At any time during the build and upon completion of any phase, work can be reviewed and documented easily, and exceptions can be logged and stored with the specification sheet in the digital work management system.

After testing and definition of use cases, the team seeks to establish and target the following key performance indicators (KPIs):

- project and product cost savings, while increasing flexibility;
- lower costs arising from rework and delays due to errors;
- lower time and skill levels required to complete all necessary steps.

In addition, complete project documentation is greatly facilitated as a result of accurate information being automatically stored in digital formats during inspection. However, feedback from managers during testing revealed multiple obstacles which need to be overcome in order to successfully introduce AR.

4 Common AR Obstacles in Manufacturing

The most common problems raised during interviews at DreamerBoat Inc. with manufacturing experts are described in the next sections.

4.1 Expectations of Business Line Managers and Corporate Executives

Business line managers and corporate executives at DreamerBoats are generally cautious about the introduction of new technologies due to uncertainty and costs as well as delays that emerged from past, insufficiently mature technologies. Hurdles that came up during the testing phase have reinforced their lack of confidence in AR-assisted tools. They deem AR to be easily overpromised and flashy. They are not convinced that AR addresses their needs or meets their requirements. Furthermore, DreamerBoats' managers place high value in their company's current working style and delivery of high quality, customized products. Changes in the production process are generally hard to push through. The fact that competitors do not use AR enhances the opinion that there is no need for AR adoption at DreamerBoats either. Thus, the challenge is to demonstrate and convince the line managers and corporate executives that the benefits of AR outweigh the risks.

Strategies to overcome this barrier:

4.2 Upgrading or Investing in Modifications of Existing IT Infrastructure

The IT Infrastructure is continually evolving at DreamerBoats. Although Internet connectivity is usually provided, it is still an issue for AR because the network latency is high and the quality varies throughout the plant, depending on the worker's position. Also compatibility with existing technical documentation, workflow management and security systems is problematic. Some of the systems that could be integrated with AR are offline (e.g., production plans are stilled transferred via USB sticks between laptops). The challenge is to introduce AR while continually upgrading existing infrastructure to enable reliable and rapid digital delivery of information within the factory. Once delivered to the worker's display, precise positioning of virtual information in relation to real world objects remains an unsolved challenge.

Strategies to overcome this barrier:

4.3 Resources, Budget, ROI, and Scalability

Software and hardware for AR is still very expensive and the CEO of DreamerBoats is not willing to invest as much in software and hardware that are still rapidly evolving. Also, for a variety of reasons, the use of AR is not applicable to all projects and processes. The management team wants to see scalable projects in order to invest fully in AR. Moreover, it is difficult to find IT staff that is specialized in the design of new digital processes and content for AR technology. Therefore, DreamerBoats

staff in many roles across multiple departments must increase their understanding of AR strengths and limitations and invest in the new tools and people to make AR effective and scalable.

Strategies to overcome this barrier:

4.4 Legal (Workers' Rights)

Since workers in spaces where AR is being used may be or are filmed and recorded during the performance of their tasks, individual privacy issues arise. Workers complain about being controlled and surveilled (watched by "big brother"). They express feelings of anxiety and lack of trust or respect by the company. In addition, those who are not employed by the company, such as suppliers and clients, who need access and interact with workers onsite may object to having their likeness and movements captured or tracked by workers wearing AR smart glasses.

Strategies to overcome this barrier:

4.5 Health and Safety Issues to the Workers

Worker health and safety issues arose during DreamerBoats' pilot testing phase. One of the workers was too focused on the digital content on the screen and lost track of the real world and his surroundings. When disoriented, the worker's head encountered a ship propeller. Another employee fell down a flight of stairs due to not seeing the stairs while focusing on the field of view containing introductory or calibration content and moving backwards to complete the tasks. Other employees may complain of headaches, eye strain and dizziness while working and wearing smart glasses for extended periods of time. Those health-related issues are a big hurdle to the adoption of AR and urgently need to be solved.

Strategies to overcome this barrier:

4.6 Lack of Acceptance

Currently, one of the biggest issues facing AR adoption is workers' lack of confidence and acceptance. They do not experience benefits from AR use immediately or consistently. After initially being curious about the use of AR, they become resistant. Workers at DreamerBoats have become frustrated when working with AR and their willingness to use the devices on a regular basis has declined. When asked to explain their reluctance and resistance, no clear statements are given to the plant managers. Workers simply state that this new technology doesn't work, interferes with their methods, is not necessary or does not bring the proposed benefits to their performance.

Discuss:
What could potential barriers (i.e., reasons why workers are against AR) be?

What could potential benefits (i.e. reasons why workers are for AR) be?

How could DreamerBoats reduce the (perceived) barriers and strengthen the perceived benefits?

5 Tasks and Background

Your task is to consult DreamerBoats during the implementation process. For each section, you find a blank box for your suggestions. Please discuss how DreamerBoats should deal with each situation. If necessary, make assumptions.

5.1 Resources

To find answers to these questions, some background research might be useful. Leading blogs and magazines can provide insights into successful case studies, and academic research might give you a better understanding of how certain things happen and interrelate. The recommendations listed below are not complete and newer resources might come up. Therefore, consider them as a starting point only.

Industry Resources

- AREA Blog (thearea.org) provides resources related to AR topics in enterprise settings. Some materials are exclusively available for members but others are public.
- The Thomas Blog provides information on different topics relevant for the industrial marketplace, amongst others articles on AR in manufacturing (https://blog.thomasnet.com/augmented-reality-manufacturing).

Academic Studies

- Research on AR, privacy concerns and other risk factors can be found in Rauschnabel, He, and Ro (2018).
- A summary of acceptance research for AR can be found in Chuah (in press).
- Alcácer and Cruz-Machado (2019) review and discuss different tools for manufacturing 4.0 tools.
- Bottani and Vignali (2019) analyse and review the scientific literature relating to the application of AR technology in the manufacturing industry.
- Jetter, Eimecke, and Rese (2018) focus on the key performance indicators (KPIs) that are able to benchmark the impact of using ready-for-market AR tools on automotive maintenance performance.

5.2 About this Research

In 2018, the AREA has launched a new project, defined and voted for by the AREA members, targeting barriers to AR adoption in manufacturing. While many manufacturers have implemented AR trials for a while, proofs of concept, and tests, relatively few have rolled out fully industrialized solutions throughout their organizations. The goal of this AREA research project was to identify issues and possible strategies to overcome these barriers.

This is the first AREA research project that focuses on a single industry in which there are many use cases that can improve performance, productivity and safety, and reduce risks and downtime. The final project contains of both quantitative and qualitative components and the deliverables will include an AREA member-exclusive report and a framework for identification of common barriers and the best mitigation strategies.

This case study was based on interviews with 16 managers with different background from different industries. The interviews were conducted in 2018. A previous version of this case study had been published on the AREA website in 2019.

5.3 About the AREA

The AREA (thearea.org; Augmented Reality for Enterprise Alliance), led by Mark Sage, is the only global, membership-funded non-profit alliance dedicated to helping accelerate the adoption of Enterprise Augmented Reality by supporting the growth of a comprehensive ecosystem. From conversations with over 500 companies interested and investing in Enterprise AR, including enterprises who have implemented solutions, providers of AR technology, and non-commercial organizations, as well as the supporting case studies the AREA is collecting and sharing with the ecosystem, it is clear that companies deploying AR are gaining real, tangible benefits. Enterprise AR is solving or improving business problems including:

- Relevant data – presenting only the latest, contextual and useful information to workers, when they need it
- Better resource management – making experts available to the entire workforce
- Real-time compliance – capturing, recording and certifying processes for policy compliance
- Reduced time – improving the efficiency of infrequent and complex tasks
- Minimized errors – preventing human error and miscalculation
- Lower costs – lowering the impact of task interruption and errors.

Through the work of the AREA members, a few barriers to adoption have already been identified. These barriers include a combination of technology and business issues such as safety concerns, security issues, a lack of shared and agreed requirements for key use cases, and improvements to the User Experience when using AR. Moreover, more research and information into the questions business leaders have are needed before they are willing/able to invest in enterprise AR.

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