
A Survey of the State of Research on Augmented Reality from a Business Perspective using Porter's Value Chain

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Abstrak

Dalam beberapa tahun terakhir, teknologi augmented reality (AR) telah mampu menunjukkan lebih banyak dan lebih mengesankan potensi yang dibawanya bagi perusahaan dan aktivitas nilai tambah mereka, dan ini meskipun penerimaan teknologi di masyarakat baru saja dimulai. Karena itu, pekerjaan kami bertujuan untuk memberikan gambaran menyeluruh tentang peluang penerapan AR berdasarkan rantai nilai, memaksa simbiosis demonstrasi potensial dan promosi penerimaan. Untuk penyelidikan kami, kami mempertimbangkan makalah peer-review yang paling penting tentang keadaan penelitian tentang augmented reality dari perspektif bisnis dan memberikan tinjauan komprehensif tentang kemungkinan penggunaan AR yang berbeda dalam suatu perusahaan, yang disusun menurut rantai nilai Porter, serta sebagai pandangan pada penelitian masa depan tentang perluasan dan pengembangan lebih lanjut dari sistem AR. Berdasarkan ini, kami merumuskan kesenjangan penelitian untuk pekerjaan masa depan pada AR dalam konteks yang disajikan.

Kata Kunci: AR, augmented reality, perspektif bisnis, Rantai Nilai Porter

Abstract

In recent years, augmented reality (AR) technology has been able to demonstrate more and more impressively the potential it brings for companies and their valueadding activities, and this even though acceptance of the technology in society is only just beginning. Due to this, our work aims to bring a comprehensive overview of AR deployment opportunities based on the value chain, forcing a symbiosis of potential demonstration and acceptance promotion. For our investigation, we consider the most important peer-reviewed papers on the state of research on augmented reality from a business perspective and provide a comprehensive overview of the different possible uses of AR within a company, structured according to Porter's value chain, as well as an outlook on future research on the expansion and further development of AR systems. Based on this, we formulate research gaps for future work on AR in the context presented.

Keywords: AR, augmented reality, business perspective, Porter's Value Chain

Introduction

In recent years, augmented reality (AR) technology has become increasingly popular and has repeatedly shown the great potential it holds for a variety of applications, especially for the business environment, although adoption is still considered low [1], [2]. This transformation within companies is an advancing process under the umbrella term of digitization, with AR being defined as one of the technologies for Industry 4.0 that can elementally advance the horizontal integration of value networks, vertical integration within a value creation system, and end-to-end technical integration across the entire product life cycle [2]. The relevance of the technology can also be seen in the fact that numerous well-known and innovative companies, such as Nike, Ikea, Google, or Nintendo, are integrating AR technology for the development of interactive media, the design of advertising or to improve the consumer experience, with AR also being envisaged to improve internal structures and value chains [3], [4]. Primarily, the goal of AR is to enable images from the real world to be supplemented by various objects in a virtual environment, i.e., to integrate virtual objects in natural space, clearly distinguishing it from virtual reality (VR), which is a completely artificial, synthetic world [1]. AR forces the possibility of being a technology that allows combining layers of virtual reality with the physical environment, which becomes possible with the help of user-friendly interfaces for the representation of three-dimensional objects by means of hardware and software [1]. This scenario is defined as a blurring of terminological boundaries, where synonyms have emerged such as "hybrid reality", "immersive VR", "mixed reality", or "programmed reality", creating the

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need for further theoretical studies on the application of AR technology in the business environment to provide clarity, but also to reveal the practical significance for businesses [1].

AR extends the user's perception with additional computergenerated [5], [6], contextualized information [5]–[8], or directs the user's focus to relevant objects in the real world [5]. This serves to improve the user experience [7]–[10]. According to [11], to be able to facilitate this improvement, AR systems should have the following three characteristics:

- they combine the real and the virtual
- they are interactive in real time
- they are registered in 3D

In the following, we will look at all the major scientific papers on AR from an enterprise perspective and provide a comprehensive overview of the potential applications of AR within an enterprise as well as an outlook on future research to expand and further develop it. As a result, this paper provides a comprehensive overview of the potential applications of AR within an enterprise as well as an outlook on future research to expand and further develop the same. The investigation topic AR from a business perspective results in the research question to what extent a company can benefit from the introduction of AR, which will be investigated finally. The resulting application areas are then structured according to Porter's value chain to cover companies to the greatest possible extent [12]. The relevance of this research question arises from the technical progress [13] in the fields of optical engineering, computer science [14], virtual reality, computer vision and robotics [15], as well as the steadily increasing number of major technology players such as Google, Microsoft, Apple and Sony in the AR market [16]–[18], which is expected to lead to a rapid spread of low-cost, high-quality products in the consumer market in the near future [15], [16].

Methods

To filter out the relevant results from the published literature, a systematic literature search was carried out using the keyword combination "augmented reality" and "business" in the literature databases IEEEExplore DL, ScienceDirect, SpringerLink, and ACM. We deliberately limited ourselves to the word business only, although there are synonyms such as enterprise, corporate or industry, but these should be largely covered by the resulting citation network and based on "business" the most relevant results were found, which was tested in advance. The search resulted in a total of 337 articles that contain the specified search word combination in the metadata or in the title, abstract, and keywords. After these articles were manually reviewed for corporate relevance using the four-eyes principle [19], 59 articles were classified as relevant from a business perspective. This was supplemented by a forward and backward search to capture the basic information on the research topic, allowing a citation network to be created. To ensure that only significant scientific work is considered in this research, only peer-reviewed journals and conference papers were examined. After these articles had been manually reviewed, those that were considered relevant to the research subject were analyzed in the comparison. When selecting the scientific articles, attention was paid to the topicality of the papers to present the current state of research as concretely as possible.

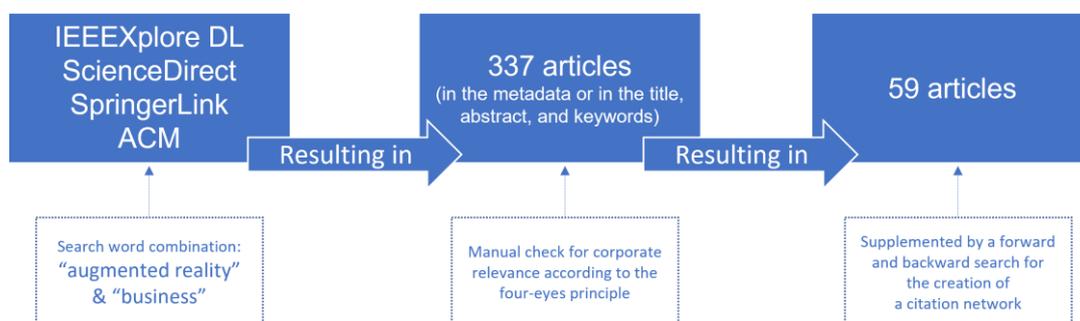


Figure 1. Procedure of the systematic literature search

Results

To date, AR has been deployed primarily via head-mounted displays (HMDs) or smartphones, with smartphones having the advantage of being convenient, ubiquitous, easily accessible, and affordable [8], [13], [20]. Explicitly, this cost-effectiveness provides the opportunity to deploy such systems in the enterprise environment, usually focusing on a value creation process. Due to this, this work will classify AR applications according to Porter's value chain, as these define the enterprise activities of a creation process and best cover the individual fields of an enterprise [12]. According to Porter, the areas in which such systems are already being used or in which implementation appears possible include the primary activities of inbound logistics [21], operations [9], [22]–[26], marketing and sales [22], [27]–[30], outbound logistics [24], [31] and customer service [9], [23], [32] and in the secondary activities of corporate infrastructure [13], [15], [32], human resources management [33], technology development [24], [25], and procurement [34]–[36].

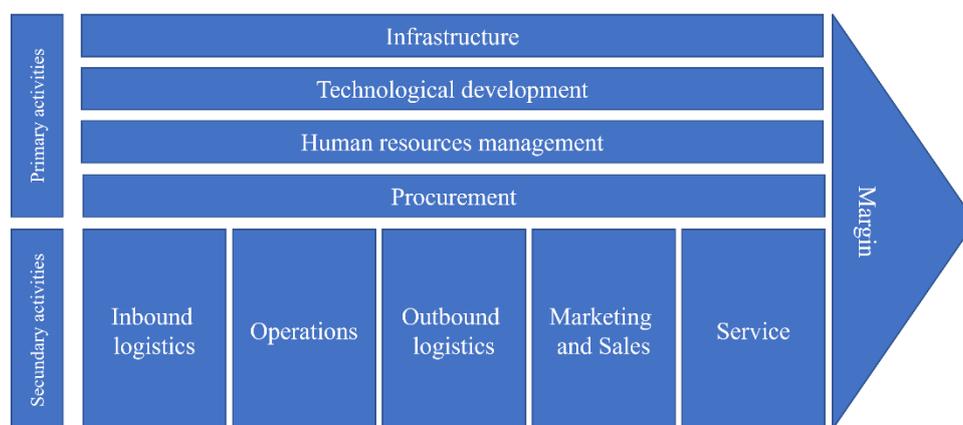


Figure 2. Porter value chain; in accordance with [12]

Inbound logistics

AR is seen as the next big change in the field of logistics, with the potential to optimize the execution of multiple logistics processes [21]. According to Porter's value chain, logistics is divided into inbound and outbound logistics, with inbound logistics potentially applying AR when goods arrive. The unloading area of the goods should be displayed for the arriving truck driver so that the goods can be processed as quickly as possible. Subsequently, the AR system checks the completeness of the delivery based on the delivery bill [21]. If the delivery is complete, the warehouse operator receives exact directions to the storage location via indoor navigation. This type of navigation can be implemented via HMD or handheld device [13], [22], [26], [31]. This development is fostered by more efficient combinations of laser scanners and barcodes, allowing new technologies such as AR to be more effectively integrated [37]. Using AR visualization techniques, employees can be intuitively guided to a new product to be stocked and easily note or report inventory updates, facilitating the management of available stock and effective product location, especially in larger facilities [37]–[39].

Operations

Within production and assembly, respectively according to Porter [12] the so-called operations, there are also possible applications for AR [9], [16], [24]. In this area, HMDs are preferred because the user still has both hands free for processing his task and the information is adapted to his perspective. In this context, AR enhances technical documentation with helpful text, images, videos, computer-aided design (CAD) models, and animations. The benefits of AR come to the fore primarily in the assembly of complex products, where the working time required to study the instructions, locate the parts, and assemble them in the correct sequence can be significantly reduced [16]. In the automotive industry, AR is being integrated into welding in the form of Mounted Projectors, as workers can now focus solely on their work and do not need to keep track of an additional schematic. HMDs are not practical here because they unnecessarily

restrict the welder. In addition, AR has the potential to maintain performance even during sleep deprivation [24]. For example, for shift workers performing repetitive tasks, this is a way to avoid errors caused by fatigue, reducing error rates and time spent [24]. Furthermore, AR can better connect sales with production by integrating the customer into the design phase and manufacturing process [30], which will be explained in more detail in the next point.

Marketing and sales

If we now consider the areas of application of AR in the field of marketing and sales, we are mainly talking about customer integration [28], [30] as well as the improvement of the customer experience [3], [27]. The industry is challenged to react quickly and effectively to constantly changing market requirements caused by globalization, profitability efforts and market saturation due to mass products [30]. A first example of customer integration can be found in the shoe industry, where a so-called “Magic Mirror[s]” enables customers to create their personal dream shoe [40]. An AR-supported mirror is equipped with a camera that permanently tracks the customer’s foot to visualize their desired shoe model in the mirror image. The user can now create and configure their desired shoe in real time and then order it. Afterwards, the shoe created by the customer is sent directly to production. Consequently, the prototype here becomes the immediate product. This process results in less storage costs, as the shoe models are sold directly from the production line, which in turn means that such a project must be perfectly coordinated [29], [41]. The mere application of Magic Mirrors, which is considered an AR front-runner [27], can delight the customer, leading to an improved customer experience. In advertising, interactive 3D media can also be displayed on magazines, posters, and products [22]. For such successful implementation of AR in marketing and sales, customer acceptance is of immense importance. Customers expect AR applications to be playful and entertaining, whereas artistic and amusing content should be avoided [27].

Outbound logistics

In outbound logistics, AR can primarily be used in order picking. This area is also the most researched regarding AR. The system must make a fast, error-free, and user-friendly selection of items for an order. This is then passed on to the picker via the HMD. The AR system shows the exact location of the goods to be delivered and, in addition, which means of transport must be used to bring them to the delivery point. Once there, the goods are loaded, with AR indicating the optimum location in relation to the delivery time. Before the goods are shipped, the system checks whether all parts have been loaded [21]. AR is also used in the subsequent delivery [13]. These are defined as so-called driver assistance systems (DAS) [9], [42], which are designed to take over navigation and increase the safety of all stakeholders [9], [31]. The advantage of AR-based navigation is that the route can be displayed directly in front of the driver’s eyes [31]. Furthermore, the driver can be informed about upcoming turns and speed limits [43]. Furthermore, so-called see-through systems make areas visible that would otherwise not be visible. These include, for example, the blind spot, visibility through the vehicle pillars, visibility through vehicles during overtaking maneuvers, as well as visibility through fog and poor weather conditions [9]. This is implemented by a Head Up Display (HUD), which can also display additional relevant and contextual information and thus further increase comfort and safety [22].

Customer service

AR can also be found in a variety of applications in the field of customer service according to Porter’s value chain [9], [12], [23], [32]. AR can be used in repair or maintenance, for example, to identify different engine components and then map information such as schematics, specifications, repair procedures, or maintenance procedures on or next to the real part [28], [32]. In addition, the AR system can also provide practical assistance to the user in opening a device as well as replacing various parts [32]. In this regard, like operations, AR enhances technical documentation with helpful texts, images, videos, CAD models, and animations. This feature is extremely useful in the maintenance of complex devices, as the time required can be significantly reduced [16].

Corporate infrastructure

The secondary activity corporate infrastructure uses AR to connect the different areas of a company [13], [15], [32]. One is in the case of the “Office-of-the-Future”, where several physically distributed spaces are virtually brought together. This allows users who are at their own desks to interact with each other in a shared virtual workspace. Furthermore, this technology can be used for video conferencing, where the distribution of seats can be adjusted to allow eye contact with all participants [15]. Furthermore, a virtual desktop on a physical desk, enables interactions with real and virtual documents [32].

In addition, internal corporate documents can be managed by AR in a context-sensitive library management system that can, among other things, alert users to their searched document with a visual cue [13].

Human resources management

Another secondary activity is human resources. AR is seen here to increase the user experience and thus the motivation of employees [33]. This is referred to as gamification. This describes the methodology of integrating video game elements into non-video games [27], [33]. These elements would be, for example, an internal list of best performers in the company, a level for each employee, or the visualization of progress. Gamification aims to increase the self-esteem of employees through a sense of achievement, such as mastering tasks. The first concrete application possibilities can be seen in the personnel of the production department. Since countable outputs are generated here, these can be visualized directly in a leaderboard. Gamification is still in its infancy in industry, but in other areas such as education and medicine, it is already an integral part. From a corporate perspective, there is still a need to catch up [33].

Technology development

In the secondary activity of technology development, AR is also being integrated in the form of HMDs [17]. The biggest advantage of HMDs here is that the user can access the desired information related to their work in real time and still move both their hands freely and not be restricted in any way [16]. With the release of HMD prototypes by the major technology players such as Google, Microsoft, Apple, and Sony, it is possible to conduct hands-on studies in natural environments, further driving the advancement of AR [31]. As AR in itself is a technology on its way to general adaptation, the field of technical progress is also to be related to AR itself, as the ever emerging applications also bring opportunities to cooperate with, bring forth or further develop other innovative technologies [44]–[46]. Especially innovative technologies such as virtual reality (VR), blockchain technologies, as for example in intelligent mobile augmented reality (IMAR) projects, or a future metaverse benefit from the development of AR, as intersections keep emerging, which is ultimately extremely interesting for companies, on the one hand financially, on the other hand image-wise [45], [47], [48].

Procurement

Within procurement, the use of AR is arguably the least widely integrated and explored, yet this area is vulnerable to adoption by AR technologies, if one considers when drawing comparisons from marketing [34]–[36]. For procurement, AR technology would also “bring to life” procurement capabilities, allowing users to, for example, haptically and visually place the materials to be procured in the real world, making possible use of HMDs conceivable [34]. Another opportunity for procurement integration holds the time dimension of resources to consider [35]. AR brings the possibility individual physical resources which can be procured directly locally to identify, supervise and pursue, with which a direct connection between Building Information Modeling (BIM) and Enterprise Resource Planning (ERP) is conceivable on the basis bar code, RFID, or GPS [35]. In addition, AR is an option for integrating 5D-CAD for quantity takeoff of materials, for example, to show the use of equipment, labor, or tools [35]. The prospects are promising, yet AR has hardly been explored in procurement and has not been considered intensively enough, which should change in the future, as potentials for companies can also arise [34].

Marging

The yield of Porter’s value chain is the margin that a company aims for. Just how profitable AR can be seen in the smartphone game “Pokemon GO” [49]. This is considered one of the biggest successes of AR, as it had over 75 million downloads after less than a month [18]. From its release on July 6 to August 24, 2016, it took in \$222 million, with 21 million active daily users and around 700,000 downloads per day. From this, this is a good example of integration and acceptance of AR [49]. Through extensive basic research in laboratories, it is only necessary to further develop existing prototypes, which leads to a rapidly growing global market [31], [50]. Some notable representatives of AR products currently on the market are Microsoft HoloLens, Epson Moverio, and Meta 2 [10], [20], [22].

Discussion

Through our research, it has become clear that predominantly the AR applications to date only serve a single purpose and are thus also only used for a short period of time, namely in the performance of the respective activity [22]. Thus, there are many devices that solve specific problems well, but consequently are not adaptable and transferable to other application domains [21], [25]. Moreover, each

application needs specific prerequisites, which prevents a generalist approach [16], [21]. Thus, there is a need for research on AR systems that enable continuous multi-purpose use. The difficulty lies in creating general purpose applications while still enabling intuitive work based on efficient memory and power capabilities. More advanced functions often need to be manually controlled and are rarely implemented in the same device [51]. Even if the functions were directly available, the question is how the user should perform them in an intuitive way without using their hands [25], [51], [52]. where employees at the point of care also find it difficult, if not impossible, to use smart systems with their hands, as those are needed during work [53]. That's why research is being done on smart glasses with the addition of audio-based and physical interaction, which should enable hands-free use [53]. A conceivable interaction would be, for example, eye blinking or giving sounds or commands verbally [53]. There is nonetheless a gap in research regarding interaction with virtual information. So far, in AR applications, virtual objects can only be seen (visual), but not touched (haptic) [18], [52], [54]. So far, only pseudo-haptics is possible, which illudes the sensory impression [54]. Furthermore, the chemical senses (smell and taste) have not yet been involved, with potential customers first needing to be convinced of the benefits of stimulating these senses, as this often results in correspondence bias [55]. Nevertheless, there is initial work that explicitly involves the senses, such as that of Wang et al. [56], which explicitly focuses on smelling, or by Kerruish [57], which aims at smelling and feeling, which also covers haptics. Explicitly integrating smell into the digital world, which is also called digital smell, should still be a long way off, which is because there are thousands of detectors involved in the human sense of smell, so that a mixture of a small number of "primary smells" defines itself as extremely complex to encode [57], [58]. In addition, people often have difficulty recognizing and naming even the most familiar odors [57], [59]. Thus, there is a need for research regarding the multisensuality of AR applications.

Limitations

The limitation of this study was the transparency of the works to be compared, since not all of them provided the full information required. Moreover, it was limited to the selected essential procedures and models, which means that in future possible further and innovative procedures will have to be analyzed, which turns out to be very likely, due to the immense evolution of the research field.

Conclusion

All major peer-reviewed journals and conference papers - supplemented by a forward and backward search - on AR from an enterprise perspective were considered, and a comprehensive literature search was conducted. The search was structured according to Porter's value chain and offers suggestions for future research in this area. The structure of this work results from the fact that a basic overview of AR possibilities of the individual value chain activities are of elementary importance in order to be able to act purposefully in the application or to expand it in the future. Furthermore, research gaps for future research in this area were identified. Future work should systematically address the formulated research gaps.

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