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Envisioning future applications of Augmented Reality: An agriculture 4.0 case study

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This paper proposes a framework of explorative methodologies to explore future applications of Augmented Reality (AR) technology. Through a case study focused on agriculture, the paper successfully demonstrated how the combination of explorative and analytical methodologies in the framework is able to translate creative and futuristic visions into actionable key factors that can be addressed today.

Augmented reality; agricultural industry; future studies

1. Introduction

Augmented Reality (AR) technology has been around for decades. The term AR was first used in the 1960s [1]. Multiple trend reports and academic articles have been positive about this technology recently. [2] [3] [4]. Theoretically, it could disrupt how humans work, interpret, and interact with information and digital insights [5]. In reality, the technology is not mature enough yet. Adoption remains relatively low due to insufficiently available AR applications. This is mainly caused by the limited technological capabilities of today's technology [6]. However, these are expected to advance in the near future [2]. Therefore, this paper discusses and introduces an explorative approach to look beyond today's limitations and envision future AR applications.

1.1. Augmented reality technology

Augmented Reality (AR) technology allows users to interact with virtually projected information directly in the desired context in the real world and in real-time [7] through devices such as head-mounted displays and mobile devices [10]. This opens up new ways of interacting with information and graphical elements. Theoretically, this can revolutionise information management and provide new insights directly on the spot at the right time. In practicality, there are only a few usable applications. This is mainly caused by the limited technological capabilities of today's technology [6]. However, as said, it is expected that these capabilities will advance in the near future.

1.2. Explorative approach

An explorative approach is useful for planning and essential to look beyond the limitations of today [8], especially in a fast-emerging environment and technology such as AR. In a rapidly changing world, the current state-of-the-art will be outpaced when the developments are market ready [9]. Furthermore, incremental improvements have proven beneficial but are prone to being outpaced by disruptive new ideas [10]. Therefore, this explorative approach focuses on the possibilities in the distant future. To look beyond incremental improvements and envision what disruptive improvements could encompass [9]. This approach could help to steer product development in new directions.

1.3. Case study explanation

A case study on the agricultural industry will be performed to demonstrate this explorative approach. This industry is known for food production and its generally labour-intensive practices [11] and conservative approach to technology adoption [12]. Generally, farms rely on robust and proven technologies that directly impact their yield output and productivity. However, the global demand for food has been rising [13] [14], mainly caused by population growth which is expected to increase even further over the next century [15]. Because of this rising demand, the industry is gradually embracing digitalisation technologies, which have become more readily available recently [16]. As a result, this presents an ideal case study to illustrate how AR technology can positively impact the daily workflows of farm labour.

2. Theoretical background

The theoretical background provides insights into the current AR application fields, the trends in agriculture 4.0, as well as the corresponding future challenges for the industry.

2.1. AR application fields

As said, AR used to be seen as a gimmick. However, it has recently gradually been getting implemented in numerous professional settings, including *Education* [17]*, healthcare* [18], *manufacturing* [19]*, and construction* [20]. Most hardware providers focused on professional applications rather than consumer devices. AR has therefore been proven to be of added value in a professional setting, enhancing tasks and workflows.

2.2. Agriculture 4.0

Driven by the rising demand for food, farmers have gradually embraced new technologies to enhance their farming productivity and total yield, shifting from traditional small-scale farming practices to large, industrialised farms [21]. Recently, digitalisation technologies have enabled farmers to gain insights into several domains of their farms [22]. This digitalisation trend in agriculture is referred to as Agriculture 4.0 [23]. However, this rapid industrialisation of the agricultural sector is likely to introduce a new set of global problems and challenges.

2.3. Global agricultural challenges

The growing demand for food required farms to grow and industrialise rapidly. However, endless growth is often not possible due to limited resources. Therefore, keeping up with this demand will introduce a new set of global farming challenges. Six challenges have been identified: *A. animal welfare, B. climate impact, C. labour shortages, D. management style, E. profitability,* and *F. supply chain traceability*. These challenges can seriously harm the industry and must be solved to remain in business and satisfy the demand for food.

3. The framework of explorative methodologies

Figure 1. displays the framework of explorative methodologies. The framework starts with a general investigation of one or more global challenges to be solved. Furthermore, as well as radical new solutions and potential technology to enable these solutions. [24]. After background research is conducted, the findings will be used in the following explorative methodologies.

3.1. Moonshot creation

Moonshot thinking is a mindset that involves creating an ambitious vision to solve complex problems. It encourages disruptive innovation, risk-taking, interdisciplinary collaboration, and a long-term vision [24]. This is achieved by combining the following three elements [25]:

1. A huge problem that affects millions of people globally.
2. A breakthrough technology that gives us a glimmer of hope that the solution could be possible in the next 20-30 years.
3. A Radical Solution which might seem unreachable today.

When these three elements are combined, the moonshot creation can be concluded with the statement of a future vision, describing how the technology can contribute to solving the global challenge by envisioning radical solutions.

3.2. Backcasting scenarios

Backcasting differs from forecasting in that it starts with a futuristic vision in mind and then works backwards from that future to the present to strategise and visualise how this vision could be achieved [26], [27]. In backcasting, the goal is to gain insight into potential developmental paths toward a desired future vision. In contrast, in forecasting, the goal is to identify a range of possible, plausible or probable futures [28].

Backcasting is done by defining a number, 'n', of phases and working backwards to the present. Per phase, a detailed scenario is made, envisioning how the future vision is getting to life. Focus on the user's perspective, problems, background and context, and the benefits of the solution. Technological details are not essential at this stage since these can be defined at a later moment. After formulating the future vision scenario, repeat the process backwards to the present. The scenarios have to trace back to each other logically. The timeframe between scenarios depends on the exact problem and timespan investigated and can range from ten years to a few months.

Furthermore, other perspectives, such as a system perspective, can be visualised next to a user perspective.

3.3. Logical antecedent

In order to gain insights from these future scenarios, it is essential to understand the necessary actions, conditions, and events that must occur prior to achieving the desired scenario. This is also called the logical antecedent. Therefore, this chapter focuses on identifying the logical antecedent.

This can be achieved by critically analysing the scenarios, from the present to the future vision. The biggest barriers and the corresponding key factors that contribute to overcoming these barriers will have to be identified. Once the barriers and key factors are analysed, these can be used to formulate a strategy and determine the next possible steps to get towards the future vision.

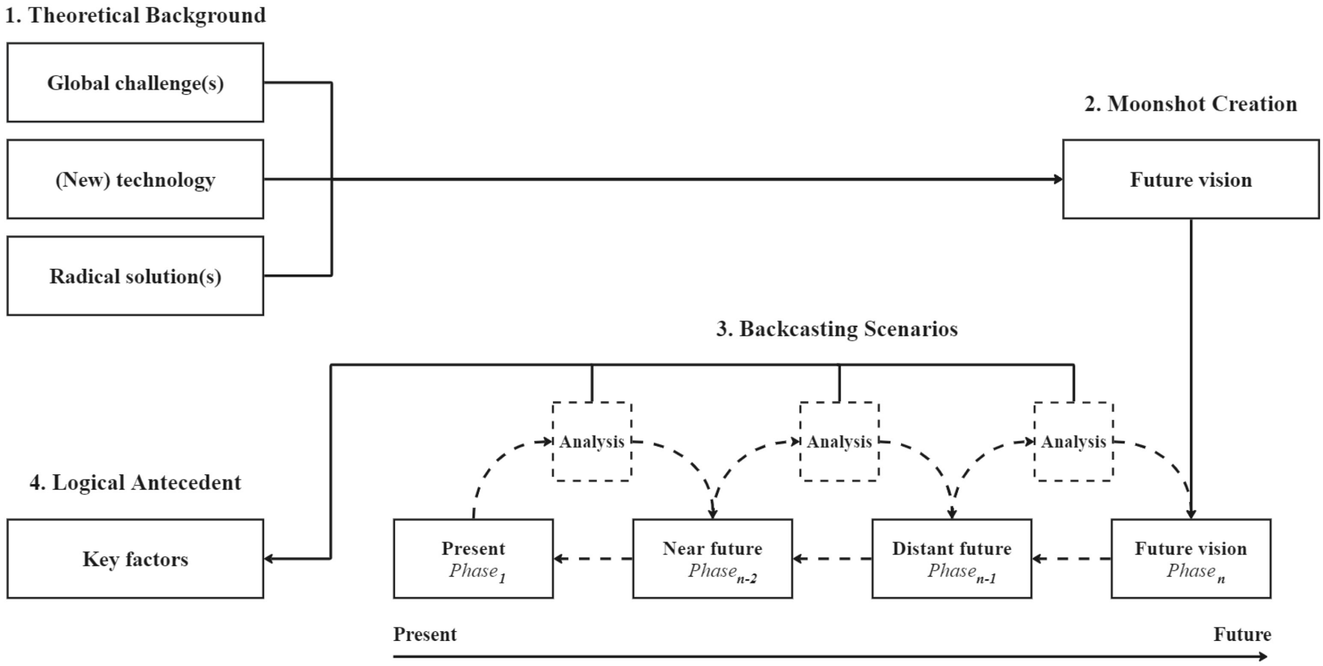

Figure 1. The framework of explorative methodologies

4. Case study: Agricultural 4.0

This section illustrates how the methodology can be applied in the case study on the future of the agricultural industry. Each of the mentioned steps will be described from the perspective of Agriculture 4.0.

4.1. Theoretical background

The methodology initiates a background analysis on three topics. First of all, the global problems and challenges have been mapped. The theoretical background has indicated that the rising demand for food has introduced the following global challenges: A. animal welfare, B. climate impact, C. labour shortages, D. management style, E. profitability, and F. supply chain traceability. These challenges can seriously harm the industry and will be used in developing a future vision.

Furthermore, the background analysis indicated how farms worldwide have faced similar challenges and adapted through technology and effective management. Two types of technological advancements were discussed: one that replaces human labour and another that enhances human labour by generating valuable insights. The remainder of the case study will concentrate on the latter type of technology, which advances human labour by generating insights.

Lastly, the background analysis delved into the potential and anticipated advancements of Augmented Reality (AR) technology. The analysis indicated that AR is steadily evolving into a more mature technology. Its abilities to display and gather data in physical space present vast opportunities. AR has already demonstrated its capacity to enhance workflows and decision-making processes in other professional industries, which can be seen as a sign that it can do the same in the agricultural industry.

4.2. Development of a future vision

The results of the background analysis have been combined during the creation of the Moonshot, in which several use cases, or radical solutions, have been developed to visualise how AR can contribute to solving the earlier-mentioned global challenges. These use cases and their contribution to the challenges have been described in Table 1.

Use case title	Global Challenge	Source
Cow Identification	*A, D*	[7]
Health assessment	*A*	[29]
Feed optimisation	*B, D*	[30]
Milking assistance	*A, D, F*	[31]
Crop monitoring	*B, D*	[32]
Soil sampling	*B, D*	[33]
Education and training	*C, E*	[34]
Remote expert assistance	*C, E*	[30]
Farm navigation	*D*	[7]
Board room management	*D, E*	[30]
Machine maintenance	*C, D, E*	[35]

Table 1. Potential AR use cases on farms

The use cases have described and visualised individual functions and applications based on sources of similar applications in various comparable industries. These use cases served as input for the formulation of the following overarching future vision:

> *"Augmented Reality enables seamless access to a real-time, bird's-eye view of the entire farm. Monitor and control all farm resources from a single interface and harness the power of data-driven insights to make optimal decisions, saving valuable time, effort, and resources."*

Figure 2. The future vision for AR in the agricultural industry

In this future vision, AR is used as an overarching platform in agricultural practices. Multiple farming domains are integrated into the same platform, which can all be accessed and controlled through a single AR platform interface.

4.3. Conversion into sequential futuristic scenarios

The mentioned future vision has been visualised using a detailed scenario. This included a persona of a young farmer in the USA and his perspectives on using the AR platform in the year 2050 for his daily practices.

Similarly, based on the 2050 scenario, preceding scenarios of the same farm with similar stakeholders have been created, illustrating a reverse chronological sequence of developments on AR back to the present. In total, four phases have been described using this methodology. In the scenario of 2040, AR is involved as a farming co-pilot. In the preceding 2030 scenario, AR is used as a farming assistant; in the present scenario, no AR is adopted on farms at all. The scenarios included a system perspective describing the advancements and coherence between the AR interface layer, the backbone data-processing layer, and a physical sensor layer.

4.4. Identifying key factors of the logical antecedent

This section analysed the differences between the four scenarios to identify key factors of the logical antecedent. Between the four scenarios, a total of three phase shifts have been analysed.

In the first phase shift, from no AR adoption to an AR assistant, the following key factors have been identified: *AR hardware, user experience, farmers' mindset, affordability, farming technologies* and *infrastructure*. These key factors need to be addressed to enable a basic rate of AR adoption on farms.

Furthermore, the analysis of the second phase shift from AR assistant to AR co-pilot resulted in the following key factors: *AR hardware, experience, integrations,* and *functionalities*. These key factors must be addressed to enable the maturation of the technology.

Ultimately, the analysis of the third phase shift, from AR co-pilot to AR platform, resulted in the following key factors: *Automation, actuation, standardisation,* and *interoperability.*

These key factors have all been mapped into a roadmap which can be used in the formulation of an AR strategy. Therefore, this methodology not only resulted in a future vision but also provided insights into the key factors to get towards that future vision.

5. Discussion of results

This framework of explorative methodologies aimed to explore future AR applications by analysing trends, defining potential future challenges and investigating how AR could potentially contribute to solving these.

The case study on agriculture 4.0 successfully demonstrated how this framework could be used to translate creative, futuristic, and often unreachable visions into insights on actionable key factors that need to be addressed in order to get towards that future vision.

6. Conclusion

Furthermore, based on the outcomes of the case study, it can be concluded that the framework of explorative methodologies can be of added value in envisioning future AR applications.

The case study has illustrated how AR can be of added value in a new industry or application field. In this case, the agricultural industry. First, industry-wide trends must be monitored and extrapolated to derive expected futuristic challenges. From here, a future vision can be created that combines these challenges with the characteristics of AR. This vision can subsequently be transformed into multiple sequential scenarios that describe the process of going from the future vision back to the present through multiple phases. These phase shifts can subsequently be analysed chronologically to derive the crucial barriers and factors of today.

In this publication, the technology augmented reality has been analysed. However, with small adaptations, the methodology can also be used for other emergent technologies.

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