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Food 4.0: Implementation of the Augmented Reality Systems in the Food Industry

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Abstract

The food industry is very resource-intensive and continuously under stakeholder's scanner to address the impact of climate change, resource scarcity, ever-changing consumer demands and stringent legislations. It has resulted in the food industry adopting Industry 4.0 initiatives for changes. In this context, one of the key focus is on enhancing transparency through Augmented Reality (AR) experiences. Although the food industry has seen a rise in the adoption of Industry 4.0 technologies, the implementation of AR remains significantly low. This paper defines AR, its benefits, and challenges, and proposes a framework for AR implementation in the food industry.

Keywords: Industry 4.0; Augmented Reality; Food Industry

1. Introduction

The increasing digitalisation in the industry, generally termed Industry 4.0, was first proposed in 2011 at the Hannover trade fair in Germany [1]. Since, then there has been a rising trend in pursuing smart and intelligent manufacturing, which has been evidenced in other countries under different names such as United Kingdom (High-Value Manufacturing), United States (Manufacturing Renaissance), India (Make in India), China (Made in China 2025), Japan (Innovation 25 Program), etc. [2]. Industry 4.0, also known as the fourth industrial revolution, is about automation and data exchange within manufacturing practices and technologies [3]. It involves connected systems, also termed as Cyber-Physical Systems (CPS), leading to increased automation, better communication, self-monitoring, and deployment of intelligent machines, which forms the basis for intelligent manufacturing or Smart factory [4].

The food industry has a significant share in the UK economy and contributes £28.2 billion (17% of all UK manufacturing GVA) annually. It is the largest manufacturing sector in the UK as it employs 400,000 people across 6,800 businesses [5]. However, due to the size of the sector, it provides significant opportunities and, at the same time, invites risks. The food industry produces a vast quantity of products with large variation, which must meet high expectations for quality and safety, with a better shelf life, as well as build customer confidence in their brand [6, 7]. Organizations that trade in food commodities are responsible for maintaining and adhering to the highest stringent regulatory standards. With the current COVID-19 pandemic situation that has created a higher demand than ever for food products and in order to develop resilience within food supply chains to provide a range of different food products, it is inevitable for organizations to address this situation as well as develop the agility in their services and offerings for the consumers without compromising on the quality [8]. Although customers have busier lifestyles nowadays, they still expect food products to be safe and of high quality, customised products that are available quickly. Therefore, the food industry needs to be agile, flexible

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and respond swiftly to the changing circumstances while being efficient and delivering a quality product at a low price and at the right time. These requirements can be achievable by embracing Industry 4.0 technologies.

The adoption of Industry 4.0 technologies is anticipated to revolutionise the food industry similar to automotive, aerospace, and other manufacturing. It will potentially substitute human intelligence and labour with technologies such as 3D printing, Robotics, and automation, etc. The application of these technologies in the food sector is termed as Food 4.0 [8]. The key design principles of Industry 4.0 involve decentralisation, interoperability, virtualisation, real-time capability, modularity, and service orientation [9]. One or more of these principles can be implemented in the food sector using Augmented Reality (AR) based technologies. These technologies allow generating, collecting and analysing data in real-time across all entities involved in the supply chain, thereby leading to better decision-making, creating new business models, and redesigning production processes and innovations. It will ultimately result in productivity increase, customisation, and an increase in income generation. Most functions carried out in the food industry are usually very labour intensive, which may be substituted with Industry 4.0 technologies, leading to creativity, solving complex issues and better decision-making. Also, research in the applications of AR technology in food manufacturing activities is a strong and growing field. However, the challenge is to design, deploy and incorporate AR-powered food manufacturing systems that could improve the food manufacturing processes, new food product development and processes, thereby resulting in shorter lead times, lower prices, and better quality.

The second section will introduce various definitions of AR. The third section will address challenges for AR implementation, while the fourth section will highlight the benefits of AR implementation in the food industry. The fifth section describes the framework needed for AR implementation in the food industry, finally followed by a conclusion.

2. Definition of AR

AR was defined as "augmenting natural feedback to the operator with simulated cues", while some described it as "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of real-world" [10]. It further refers to the Milgram Reality-Virtuality Continuum, a scale, which, when moved from left to right, increases the amount of virtual imagery, and weakens the connection with reality. However, Schueffel [11] defined AR as a superior form of the physical, real-world reality of which features are superimposed by computer-generated or extracted real-world sensory input such as sound, video, graphics, or haptics. AR merges virtual information with physical information in a user's view field [12].

In simpler words, AR can be defined as is when digital information is overlaid onto the actual physical world. Sometimes AR is referred to as mixed reality. Its main purpose is to enhance the real world with a set of magical virtual objects in it, i.e., when an individual's real environment is supplemented or augmented with computer-generated computer images, usually motion tracked, then that is AR [13]. As per Azuma [14], AR consists of three main features: merging real and virtual worlds, real-time interaction with the user and presenting it in a 3D environment.

3. Challenges for AR implementation in the food industry

AR has seen a rapid rise in its popularity Tom Caudell coined it in 1990. As per Statista, AR revenues generated from AR devices and AR services were USD 54 billion in 2018 and are expected to reach USD 186 by the end of 2020 [15]. Although the AR industry is predicted to rise exponentially, there are still some challenges in its adoption in the food industry, as depicted in Figure 1. These six challenges are derived from the extensive literature and practical experiences of the industry.

3.1 Privacy and security

Privacy and security pose a significant threat to AR implementation [16] in the food industry. In one of the recent works by Sulaiman et al. [17], the authors highlighted the cybersecurity-based challenges involved in the implementation of Industry 4.0 principles. The authors further presented a system dynamics-based perspective for the implementation of the IIoT in the manufacturing sector. Inconsistencies involved with AR programming leading to misunderstanding and ignorance can often be a cause of concern. For example, a factory setting where some food recipes are traditional and well-guarded can be easily exposed using AR. There is also a risk of other production parameters and business secrets getting compromised or manipulated via observation and mining data outputs. There is no definite directive on what is acceptable and what is not, meaning AR can be used with a vicious aim. It is also partly due to the absence of awareness and ignorance of the AR developers to take action before it becomes a more significant issue such as loss of business, market share or profit margin.

Fig. 1. Challenges for AR implementation in the food industry

3.2 Absence of a robust business model

Apart from the gaming industry, no other industry has figured out the AR-based business model that will last for significant years. There have been enough investments in AR

technology over the last few years; however, there has not been a breakthrough AR application in the industry which has paid off. For example, Domino's uses AR to help its customers to visualise their pizzas with various toppings, their actual appearance and if the size big enough for them [18]. Although AR solutions like this can attract customers, similar results can be achieved without using AR solutions.

3.3 Risk of damage or harm

AR is considered to be better than Virtual Reality (VR) in terms of applicability [19]; however, there is still a risk to damage an asset or harm an individual. Since AR works in real surroundings by adding a few digital inputs into it, this may result in accidents due to a lack of awareness about other operations happening in the surrounding, which may harm. For example, an engineer on the factory floor who uses AR to look into a machine defect may be unaware of other moving machine parts, which may cause harm or injure them as they are distracted from the actual reality.

3.4 Social acceptance

AR is gaining significant popularity and is considered one of the most exciting emerging technologies when it was launched [20]. However, still, now its acceptability among the public has met with a lacklustre response. The majority of the AR applications have not taken off, but this situation may change if people get aware of AR benefits and if there are few exceptional AR apps in the market. For example, using AR in displaying restaurant recipe menus may excite people a few times until their goals are met or fulfilled and then desert it due to the absence of long-term applicability.

3.5 Issues with regards to the poor quality

The majority of AR apps developed are currently used for demonstration purposes and are equipped with very basic features [21]. Most AR developers use the same tools again and again, such as Microsoft HoloLens and Google Glass. The other reason is the absence of enough expertise in harnessing AR to its full potential to offer valuable experience to the users. AR displays for food products appear to be a good idea; however, it seems to be ineffective solution in reality.

3.6 Technological issues

Designing an AR app for an AR device is entirely different from designing it for a smartphone [22]. The smartphone may not have desired AR experience and can encounter certain limitations making it non-user friendly. Also, AR devices are expensive and deter people from using them and instead compels them to use smartphones that have AR app design limitations. AR devices require large battery power, which is a significant issue. Considerable progress is needed to be made in terms of the battery power and computing of AR devices before it is appropriate for routine use by its users [23]. There is still a bit of latency in time between the data getting computed to AR interaction.

4. Benefits of AR in the food industry

Customers are demanding new sustainable, innovative food products with shorter lead times, safe and better quality. Therefore, the food industry should be quick to implement Industry 4.0 technologies in order to address these issues and be competitive. More benefits will be achieved through learning customer trends and delivering them fresh food products swiftly. Although it is not a new approach, but complexity in food processing makes it difficult, and it is growing at an extraordinary rate. However, the rise of AR has opened many opportunities for the food industry to tackle some of the issues and assist them in making the most out of their businesses. It helps in building a relationship using minimum resources and interact with customers easily.

4.1 Improving employee safety and efficiency

AR is already proving its worth in performing maintenance activities in the manufacturing sector. For example, an operator of the machine equipped with an AR headset can easily get step-by-step notifications of their task in their working environment using a digital overlay. Vignali et al. [24] also described the design and testing of an AR solution to improve the safety of employees when carrying out maintenance task on a hot-break juice extractor machine. AR can be used to overlay a set of functions related to inspection or processing activities for employees to adhere to as they process food products in the supply chain. It can also help in reducing the food product recall incidences by ensuring that the employees do not miss key steps during processing that may result in contamination or spoilage. Figure 2 demonstrates how an employee uses using a tablet equipped with an AR app to understand the complex process flow of a machine, displays real-time information, and identifies the faulted instruments.

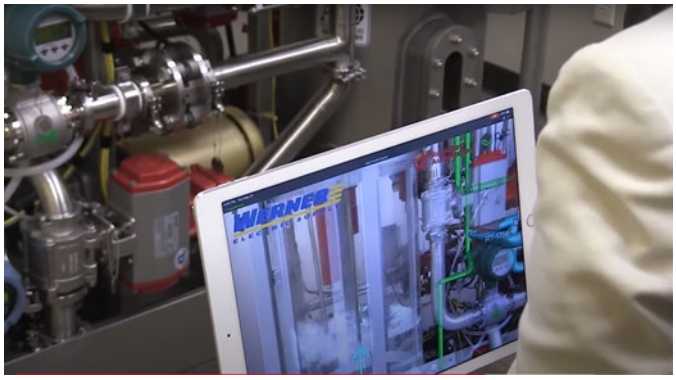

Fig. 2. Employee using AR technology to understand the process flow [25]

4.2 Enhancing the employee training

The food industry is one of the most labour-intensive sectors with high attrition rates; therefore, onboarding and training new employees is significantly expensive and time-consuming [26]. Furthermore, failure to give the employees proper training and employees to retain those training can result in dreadful consequences. The majority of these consequences happens due to non-understanding of the simpler things, lack of knowledge or miscommunication. AR removes the need for a trainer to be physically located at the training place, i.e. helping

to do more with fewer resources. It saves human resources and trains employee faster, safely, timely and with less risk.

For instance, failure to train the employees to cook properly can result in food poisoning and worse. AR could significantly lower the possibility of such incidents in the future by providing constant guidance and reminders to new employees without diverting their attention away from work [27]. Figure 3 shows how AR is being used to train an employee to carry out step by step maintenance work on a piece of equipment.

Fig. 3. Maintenance training using AR [28]

4.3 Improving efficiencies in the logistics

Food logistics is an essential aspect of the supply chain as the food products have limited shelf life and need to be stored at a specific temperature to avoid deterioration. AR can be utilised for optimised picking in warehouses [29]. For example, AR projections help the operator to identify the picking location quickly. Figure 4 shows a forklift fitted with an AR app showing the item location, distance to it and shortest path to take [30]. It considerably lowers the risk of food products left in unrefrigerated areas or possibly coming into contact with nonconforming temperatures or pathogens. It can also detect any moving objects around it warn the driver about a possible hazard. AR smart glasses can be used for efficient sorting in the warehouses, helping operators sort goods according to selection criteria. It can instantly scan the barcodes to see if they have picked the right box and to see what items are inside the box.

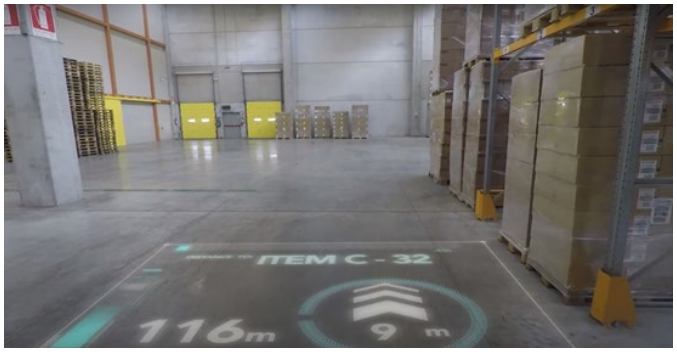

Fig. 4. AR projections fitted to a forklift [30]

The perceptual interface will help operators to minimize sorting errors. It can provide operators with visual instructions to optimize cargo loading and quickly identify the correct cargo upload area.

4.4 Enhancing new food product development

Developing a new food product can take anywhere between six months to five years, depending on whether it is a minor alteration/substitution of an ingredient within the recipe or the launch of a whole new product [31]. The majority of food manufacturers launch a couple or more new food products annually to remain competitive and retain their market share. Therefore, product development is usually a costly process in a food business considering the time and resources utilized. AR technologies similar to its application in the engineering field [32] can be used in the food sector to solve product realization problems and lead to many exciting new paradigms. For instance, AR can be used in sensory science such as consumption, biometrics, food structure and texture, sensory augmenting and augmenting sensory perception [33]. However, AR can also be used by the product developers to create a virtual product and analyze it in a real food production setting to visualize any issues they may encounter and address them while delivering a low-cost solution. AR can be used in the initial stages of food product development to minimize costs and as a tool to interact in a real-world or a simulated environment. It can also provide additional noticeable features by changing certain parameters of the food product such as its size, quality, colour, texture and consumer acceptance and evaluation [34-36].

4.5 Driving sales and using it as a marketing tool

The food industry is currently using AR to embed it into food packaging to bond with their customers and turn it into an interactive experience. All food products can be experienced by the customers virtually and are used as a tool for sales and marketing to grow businesses. With AR, food companies and catering services such as restaurants can easily simulate the impact of their packaging or products. It reduces the need for expensive physical food products and speeds up the approval cycle between the owner, designer, chef and customers. For instance, food sales representatives can use AR in an actual store to see where they can place their product in the store to increase its visibility at the point of sales. Also, they can easily access AR-powered catalogue offline, capture their in-store simulations, share pictures with their customers or even use it as a mobile 3D viewer. The customers, by using AR, can visualize the nutritional facts of a food product, as well as its origin, processes that it has gone through. It helps in better understanding of the product, people who manufactured it, thereby helping to create connections. In restaurants, menus are being created using AR, giving customers a three-dimensional image of the real dishes, view the texture of the product, their ingredients and their size using their handheld devices such as mobile phones or tablets, as shown in Figure 5.

This feature has increased appetite for the product among customers helping business to grow [33, 37]. It can also be used to monitor customer's facial expressions and emotions towards food products on the menu, providing insights into their food choices and preferences.

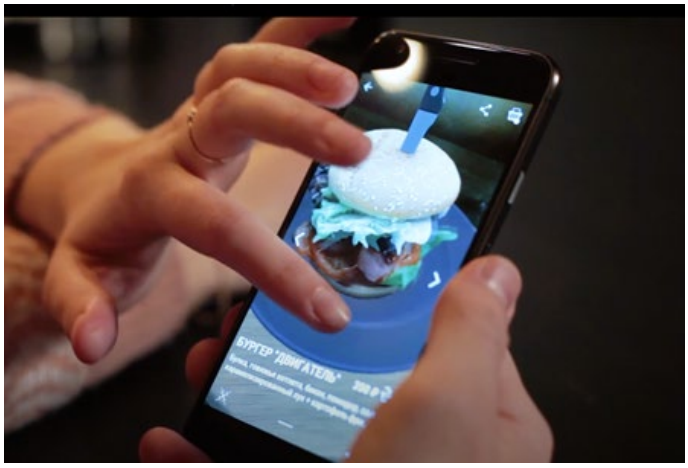

Fig. 5. Restaurant menu in AR [38]

5. Framework for AR implementation in the food manufacturing

Based on the three sustainability pillars (economic, social and environment), the following framework for AR implementation in the food factory has been suggested (Figure 6). The first stage of the framework is to understand the summary of the tasks related to plant, process and product (3Ps). It will help to establish the relationships and sequence of activities in relation to 3Ps.

The second stage is to collect, organise and integrate all the relevant information essential to 3Ps in order to develop an AR application. The purpose behind this stage is that if an employee who is entirely new to the food manufacturing environment can efficiently perform their job without any human supervision.

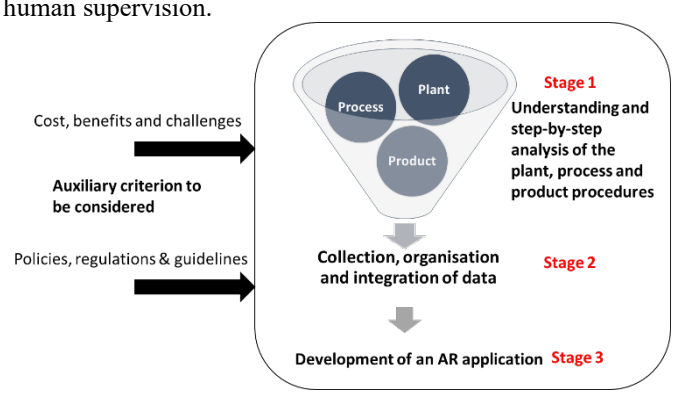

Fig. 6. Framework for AR implementation in the food manufacturing

The final stage is the development of an AR application. This stage aims to develop an AR solution for activities related to 3Ps. It includes testing and validation of the solution before its final implementation on the factory floor.

The auxiliary criterion that needs to be considered is from the business as well as the stakeholders viewpoint. The AR implementation very much depends on the costs involved in the first three stages with regards to understanding, collection and organisation. It also includes testing, validation and implementation costs. However, it could be beneficial in increasing the productivity of the staff, equipment and overall factory and at the same time reducing the accidents and other health and safety issues. The other important criterion can be with policies, regulations and guidelines which need to be adhered to while developing an AR solution. This could be especially important to satisfy stakeholders such as the government and the business itself.

6. Conclusion

As food manufacturing operations become more complex, Industry 4.0 technologies such as digitalization, data analytics, robotization, and automation will play a crucial role. However, to enhance the resources, manufacturing operations and food products must also be digitally connected. In this context, it becomes clear that AR technology will play a vital role in providing this connection for all the entities within the food supply chain. As the Industrial Internet of Things (IIoT) continues to grow, so will the adoption of AR applications in the food industry will continue to grow. Hence, this paper offers a simple definition of AR and its challenges, benefits as well as a framework for AR technologies implementation within the food industry.

The paper highlights the potential benefits of AR technologies within the food industry and summarises the challenges which currently exist for its extensive application. It also proposes a three-stage framework for AR implementation in the factory. The paper specifies numerous examples of AR implementation within the food industry that require minimum resources with a significant return on investment. However, organizations can explore further industry-specific AR applications. Some AR applications for the food industry, such as interactive menus for restaurants, are easy to create and publish. However, content value is based on the information it transfers and not the speed at which this AR content is produced. Therefore, it is important to have a manufacturing expert to ensure that content is translated into effective AR tools. The food industry can reprocess its digital assets to swiftly generate two-dimensional or three-dimensional visual aids for various functions within the business. AR tools can support complex tasks within the factory as they require more experience to execute them effectively and efficiently with minimum quality issues. It is easier to develop AR tools for repetitive tasks since less variability needs to be addressed. The food industry should consider the resources required to scale the AR application to meet potential future needs irrespective of the earlier purpose of the application. While it is clear that AR technology will play an important role in the food sector, however, it is still a very new technology, and further research will decide the course of how this technology can be fully exploited for this sector. AR technologies will continue to grow exponentially, with AR devices becoming smaller, cheaper, and more robust. It will ensure the rapid development of creative AR solutions.

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