Future Agriculture Farm Management using Augmented Reality

Mingze Xi*
CSIRO

Matt Adcock†
CSIRO

John McCulloch‡
CSIRO

ABSTRACT

Augmented reality (AR) technology is blooming in the past few years with a growing number of low-cost AR devices becoming available to the general public. AR techniques have demonstrated the capacity to optimise task efficiency in a broad range of industries and provide engaging entertainment and education experiences. However, the potential of AR has not yet been fully explored. One of the extremely underexplored areas is its application in broad agriculture sector. As a major source of food, agriculture has always been a national priority. Agriculture farming is highly labour-intensive and heavily relies on individual farmer's expertise, resulting in challenging farm management issues. We argue that AR can make critical contributions to the optimum management of agriculture farms. We take aquaculture ponds as an example, and presented three use cases to show how AR can potentially support more efficient farm management activities: water quality management, remote collaboration, and boardroom discussion.

Keywords: Augmented reality, interactive data visualisation, decision making, farm management.

Index Terms: H.5.1 [Information Interfaces and Presentation (e.g., HCI)]: Multimedia Information Systems— Artificial, augmented, and virtual realities

1 INTRODUCTION

Augmented reality (AR) is a technology that provides immersive experiences by superimposing virtual 3D objects upon real world objects [1]. This generates illusions that the virtual objects co-exists with the physical objects in the same space [1], [2].

Many studies have shown that AR can contribute to better understanding of reading materials, optimised task performance, and improved training outcome [3]. For example, AR has been successfully used in domains including education [4], military[5], [6], medicine [7], [8], and entertainment [9].

One critically significant yet extremely underexplored domain is using AR in agriculture. Agriculture has always been a national priority of governments, which has significant effects on economic and employment. For example, Australian agriculture sector contributes to over $1,700 billion per annum [10, p. 1]. Advances in agriculture have saved more than 2.9 billion lives [11], [12]. However, for such an important field, a recent survey on AR showed that agriculture is one of the least explored areas of augmented reality [13].

Modern agriculture is a highly complicated and complex system that syntheses a wide range of disciplines, such as optimum farm management, precise climate prediction, and nutrition. There are many opportunities where augmented reality can contribute and we are particularly interested in the area of farm management. We believe AR can contribute to efficiencies in farm management tasks as it has demonstrated in other domains (e.g. managing underground infrastructure [14]).

The goal of farm management is to increase the yielded biomass (total farm production). Agriculture farms can be categorised based on the type of crop, such as crops (e.g. rice and sugar), animals (e.g. shrimp, bees, and cows), and forestry. Research has shown that optimum farm management can improve yielded biomass [15]–[17] and reduce waste [16], [17].

In this paper, we take aquaculture farming, particularly the shrimp farm industry, as an example to explore how AR can help farmers optimise their farm management. Based on the review of aquaculture research and our internal focus group with agriculture researchers, the most challenging task of aquaculture farm management is managing water quality and responding rapidly to the changes of water conditions [16], [18], [19].

Water quality is one of the determining factors of shrimp health. The optimum water conditions (e.g. temperature, turbidity, dissolved oxygen) lead to optimum production, while poor water quality can cease the growth and breeding of aquatic animals, cause diseases, or even death [16]. Therefore, being able to efficiently monitor water quality is critical. However, current aquaculture farms are suffering many inefficiencies:

Firstly, the feeding decision making is challenging. The decision on when and how much to feed requires the information of dissolved oxygen (DO), temperature, and nitrates, while a farmer is working around many ponds. However, there is no widely adopted system to support this activity.

Secondly, inefficient integration with existing sensor networks. The development of Internet of Things (IoT) has enabled deploying multiple sensors (e.g. hydrophones, temperature sensors, and cameras) to monitor water conditions. Sensor data is particularly important in shrimp farming as usually the prawns are not directly visible. However, the collected water data is typically analysed in the office rather than around the ponds. This affects farmers' ability to arrange optimum feeding as the conditions can change rapidly throughout a single day.

Thirdly, poor communication between farmers in the field and farm managers in the office. Communication is critical especially when abnormal situation occurs, such as sudden changes in water conditions. Farmers need to communicate with experts (e.g. on-site farm managers or external aquaculture experts) to tackle the problem. Farmers also typically have both hands occupied while working around ponds. It can be necessary for them to share their views with experts at a remote location as sensors simply cannot measure everything. There is no existing work that can address these challenges.

The last, but not the least important, is training new farmers. Such training activity usually requires a skilled farmer to be onsite while shadowing a new farmer's pond activities. The challenge here is the lack of on-site human resources. For example, the whole Australian shrimp farm industry offers only 300 full-time equivalent jobs [20]. In this case, the time of a skilled farmer or expert is not easily accessible. Also, not all farmers are good at instructing new staff. Being able to train farmers remotely by an aquaculture expert may address this difficulty.

Recent successes in AR-based information presentation and interaction, and shared views and face-to-face collaborations have made AR a potential choice to tackle the problems in aquaculture pond management. The rest of the paper briefly reviews relevant AR research and describes three scenarios to demonstrate how AR can contribute the farm management.

2 AFFORDANCES OF AR

In this section, we review selective areas of recent AR research while keeping future agriculture scenario settings in mind. For a comprehensive review of AR research, refer to [1]–[3], [21].

*e-mail: mingze.xi@csiro.au
†e-mail: matt.adcock@csiro.au
‡e-mail: john.mcculloch@csiro.au

IEEE Workshop on Virtual and Augmented Realities for Good 2018
18 March 2018, Reutlingen, Germany
978-1-5386-5977-9/18/$31.00 ©2018 IEEE

2.1 AR Information Presentation

AR, by overlaying physical objects with virtual information, can create a "seeing space" that allows a user to perform situated analysis with a group of information presented [1], [22]–[24]. Data today is big and heterogeneous. Although more data is needed to make a decision, overly complex and poorly presented data can easily confuse the decision makers. To present only the most demanding data, researchers have attempted to filter the information before presenting them in the space. For example, Julier et al. [25] proposed an approach to filter information based on the state of the user (location and intention). Another popular filter takes advantages of Semantic Web to provide personalised information to users [26].

2.2 AR Information Interactions

Once the information is presented in the space, a user may interact with the information to seek for useful content. Shneiderman [27] suggests that a common practice of seeking information starts from an overview of the entire data collection, then zooming on items of interest, filtering out uninteresting information, and finally select a particular item to get the details. The practice is also referred to as the Visual Information-Seeking Mantra. In the case of AR, the process can be optimised by, for example, using user context to automatically filter data or cancelling out the zoom step by locking scale to the physical world. The actual actions vary between devices and environment settings. For example, Veas et al. [28] demonstrated interacting with augmented environmental sensor data using a smartphone with a graphical input panel.

2.3 AR Collaboration

Another advantage of AR is the support of collaboration between two or more users. AR supports face-to-face collaboration and remote collaboration between two or more head-mounted displays (HMD) [29], [30] as well between an HMD and a tablet or PC [31], [32]. AR enables many collaborative tasks which were not possible with other technologies, for example, experts can remotely guide the field worker via a shared view [30], [31].

2.4 Choice of AR Display

There are many types of AR displays which vary significantly in costs and targeted scenarios. At the consumer level, handheld mobile devices, such as smartphones and tablets [23], are the most popular choice which does not require users to purchase specialised equipment [3]. One the other hand, head-mounted optical see-through AR displays (e.g. Microsoft HoloLens and Google Glass) provide direct observation of the physical world, while mobile devices usually require a user to watch augmented video captured by a camera. Other displays (e.g. autostereoscopic displays, volumetric displays, and projector-based displays) are less portable and typically require specific environment setup.

Given the fact that farmers have both hands occupied while working in the field, head-mounted AR displays may be a better choice. Recently released devices (e.g. Mira [33]) may also provide head-mounted AR experience powered by smartphones. For indoor scenarios, projector-based AR could also be used [34].

3 AQUACULTURE USE CASES

We outline three use cases to show how AR can potentially contribute to core management tasks for aquaculture farms.

3.1 Optimising Feed Management

One important task of aquaculture farm management is managing feeding. Optimum feeding is critical to maximum aquatic crops. Feeding is a complex decision that considers real-time water quality and biomass in the pond, which should be planned dynamically, rigorously and systemically. One challenge, as mentioned in Section 1, is the lack of the information of water conditions while farmers are working on the farm.

Alternatively, farmers may wear head-mounted AR displays that allows them to walk or drive freely around ponds with critical information (e.g. DO, pH, biomass value) situated right at the respective ponds. Furthermore, if water quality allows, with underwater webcams installed in ponds [18], farmers may even be able to monitor the feeding through live video and adjust the amount of food appropriately to achieve the best Feed Conversion Ratio (FCR). This also can potentially help farmers diagnose crop diseases (e.g. shrimp white spot disease) at an early stage, therefore respond quickly to minimise potential lost.

There are other applied AR research opportunities here too, for example, what equipment setup best suits farmers' needs; how each setup affects user's cognitive load; and what measurable benefits (e.g. increased biomass) AR can contribute to.

3.2 Boardroom Farm Planning

As stated in [16], the key success of pond water management is to maintain stable water quality. Regular monitoring is vital in planning future effective farm management by helping predict and prevent any stress before it occurs. An AR virtual workspace allows a farm manager to see a time-series overview of data collected across the entire farm. Appropriately visualised and presented information (e.g. [26] and [23]), may allow the farm manager to interact and analyse information efficiently [27], therefore make better decisions. For example, wearing an AR display, a farm manager can augment any surface with a virtual farm model that is marked up with streamed and/or historical DO data (time series) at different depths across all ponds (geolocation data). This could potentially help managers determine how to adjust their water exchange schedule (e.g. exchange rate and time) to maintain the DO values of all ponds within the optimum range.

Besides assisting individual users, AR can also assist the collaboration between farm stakeholders. For example, planning future farm development (e.g. opening new ponds) involves groups of stakeholders, who need to observe different aspects of the entire farm data. Such process usually requires all individuals to physically meet in a board room with limited flexibility to allow remote attendance via video conference. There are two main problems with the existing form of group meeting. One problem is the farm data is highly heterogeneous that is not ideal to be plotted into 2D spaces (e.g. computer monitor and projector). The other problem is that such conventional environment setup simply does not allow multiple users to explore the big data set interactively and collaboratively. In this case, AR can potentially addresses these two limitations by providing augmented workspaces allowing face-to-face interactions around tightly co-registered visualisations of multi-dimensional data.

3.3 Remote Expert Assistance

Training a skilled farmer is a difficult task. With limited human resources, it is not practical to have a dedicated trainer who is also a skilled aquaculture farmer. However, AR allows a trainee to be trained by a remote subject-matter expert (SME) by sharing its real-time view [30], [31]. The expert can visually mark the view shared by the trainee and give audio instructions in the meantime. This potentially contribute to a more personalised, on-demand, and effective training experience.

Being able to collaborate remotely using AR also allows farmers to rapidly tackle emergent stress to the farm system. For example, sudden changes of water quality can be vital and occur any hour of the day. Delayed attendance can cause the death of farm animals. Ideally, onsite assistance from experts is required. However, this is not always applicable as farms are generally located in remote areas and require considerable amount of travel. Alternatively, a less knowledgeable onsite farmer can quickly attend the scene, then share his or her view of the pond (including relevant data) with a remote expert. Using AR collaboration technologies, the expert can provide accurate instructions to the farm while the farmer is working around the farm (e.g. [30]). There are questions that we need to answer to provide the best remote assistance. For example, what are the best practices while instructing local users in an enclosed indoor environment (e.g. an office) and those in an outdoor scenario (e.g. an open farm)?

4 Conclusion

This position paper has described some of the challenges of agriculture/aquaculture farm management and outlined opportunities where AR can contribute. There has been relatively little existing work on applying AR research in agriculture to date and, given the recent advances in AR technologies and AR successes in other domains, it is reasonable to expect that AR could potentially contribute to food production and therefore quality of life.

References

[1] R. T. Azuma, "A Survey of Augmented Reality," Presence: Teleoperators and Virtual Environments, vol. 6, no. 4, pp. 355–385, Aug. 1997.

[2] R. Azuma, "Making Augmented Reality a Reality," in Imaging and Applied Optics 2017, 2017, p. JTu1F.1.

[3] M. Billinghurst, A. Clark, and G. Lee, "A Survey of Augmented Reality," Foundations and Trends® in Human–Computer Interaction, vol. 8, no. 2–3, pp. 73–272, 2015.

[4] A. Clark and A. Dunser, "An interactive augmented reality coloring book," in 2012 IEEE Symposium on 3D User Interfaces (3DUI), 2012, pp. 7–10.

[5] DAQRI, "DAQRI Smart Helmet: GunnAR with the US Navy - YouTube." [Online]. Available: https://www.youtube.com/watch?v=tG9FPj1u2HQ. [Accessed: 14-Jan-2018].

[6] T. A. Furness, "The Super Cockpit and its Human Factors Challenges," Proceedings of the Human Factors Society Annual Meeting, vol. 30, no. 1, pp. 48–52, Sep. 1986.

[7] R. G. Thomas, N. William John, and J. M. Delieu, "Augmented Reality for Anatomical Education," Journal of Visual Communication in Medicine, vol. 33, no. 1, pp. 6–15, Mar. 2010.

[8] D. Gasques Rodrigues, A. Jain, S. R. Rick, L. Shangley, P. Suresh, and N. Weibel, "Exploring Mixed Reality in Specialized Surgical Environments," in Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17, 2017, pp. 2591–2598.

[9] Asobo Studio, "Fragments," 2016. [Online]. Available: http://www.asobostudio.com/games/fragments. [Accessed: 14-Jan-2018].

[10] ABARES, "Agricultural commodity statistics 2014," Australian Government - Department of Agriculture and Water Resources, 2017.

[11] Medigo, "Lifesaving Innovations - Infographic - MEDIGO Blog," 2014. [Online]. Available: https://www.medigo.com/blog/infographics/lifesaving-innovations/. [Accessed: 15-Jan-2018].

[12] "Science Heroes," 2017. [Online]. Available: http://scienceheroes.com/. [Accessed: 15-Jan-2018].

[13] J. Bacca, S. Baldiris, R. Fabregat, and S. Graf, "Augmented Reality Trends in Education: A Systematic Review of Research and Applications," Educational Technology & Society, vol. 17, no. 4, pp. 133–149, 2014.

[14] G. Schall et al., "Handheld Augmented Reality for underground infrastructure visualization," Personal and Ubiquitous Computing, vol. 13, no. 4, pp. 281–291, May 2009.

[15] A. J. Hobday, C. M. Spillman, J. Paige Eveson, and J. R. Hartog, "Seasonal forecasting for decision support in marine fisheries and aquaculture," Fisheries Oceanography, vol. 25, no. S1, pp. 45–56, Apr. 2016.

[16] Department of Primary Industries and Fisheries, "Australian Prawn Farming Manual: Health Management for Profit," 2006.

[17] F. Kuhlmann and C. Brodersen, "Information technology and farm management: developments and perspectives," Computers and Electronics in Agriculture, vol. 30, no. 1–3, pp. 71–83, Feb. 2001.

[18] C.-C. Hung, S.-C. Tsao, K.-H. Huang, J.-P. Jang, H.-K. Chang, and F. C. Dobbs, "A highly sensitive underwater video system for use in turbid aquaculture ponds.," Scientific reports, vol. 6, p. 31810, Aug. 2016.

[19] C. M. Spillman, J. R. Hartog, A. J. Hobday, and D. Hudson, "Predicting environmental drivers for prawn aquaculture production to aid improved farm management," Aquaculture, vol. 447, pp. 56–65, Oct. 2015.

[20] "Australian Prawn Farmers Association," 2014. [Online]. Available: http://apfa.com.au/about/. [Accessed: 15-Jan-2018].

[21] Feng Zhou, H. B.-L. Duh, and M. Billinghurst, "Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR," in 2008 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, 2008, pp. 193–202.

[22] B. Victor, "Seeing Spaces." [Online]. Available: http://worrydream.com/SeeingSpaces/. [Accessed: 15-Jan-2018].

[23] N. A. M. ElSayed, B. H. Thomas, K. Marriott, J. Piantadosi, and R. T. Smith, "Situated Analytics: Demonstrating immersive analytical tools with Augmented Reality," Journal of Visual Languages and Computing, vol. 36, pp. 13–23, Oct. 2016.

[24] N. A. M. ElSayed, B. H. Thomas, R. T. Smith, K. Marriott, and J. Piantadosi, "Using augmented reality to support situated analytics," in 2015 IEEE Virtual Reality (VR), 2015, pp. 175–176.

[25] S. Julier et al., "Information filtering for mobile augmented reality," in Proceedings of IEEE and ACM International Symposium on Augmented Reality (ISAR 2000), 2000, pp. 3–11.

[26] R. Hervás, A. Garcia-Lillo, and J. Bravo, "Mobile Augmented Reality Based on the Semantic Web Applied to Ambient Assisted Living," in Ambient Assisted Living: Third International Workshop, IWAAL 2011, 2011, pp. 17–24.

[27] B. Shneiderman, "The eyes have it: a task by data type taxonomy for information visualizations," in Proceedings 1996 IEEE Symposium on Visual Languages, pp. 336–343.

[28] E. Veas, R. Grasset, I. Ferencik, T. Grunewald, and D. Schmalstieg, "Mobile augmented reality for environmental monitoring ¨," Personal and Ubiquitous Computing, vol. 17, no. 7, pp. 1515–1531, 2013.

[29] D. Schmalstieg et al., "The Studierstube Augmented Reality Project," Presence: Teleoperators and Virtual Environments, vol. 11, no. 1, pp. 33–54, Feb. 2002.

[30] O. Oda, C. Elvezio, M. Sukan, S. Feiner, and B. Tversky, "Virtual Replicas for Remote Assistance in Virtual and Augmented Reality," in Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology - UIST '15, 2015, pp. 405–415.

[31] H. Chen, A. S. Lee, M. Swift, and J. C. Tang, "3D Collaboration Method over HoloLensTM and SkypeTM End Points," in Proceedings of the 3rd International Workshop on Immersive Media Experiences - ImmersiveME '15, 2015, pp. 27–30.

[32] S. Barathan, G. A. Lee, M. Billinghurst, and R. W. Lindeman, "Sharing Gaze for Remote Instruction," in ICAT-EGVE 2017 - International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments, 2017.

[33] "Mira Prism Augmented Reality Headset," 2017. [Online]. Available: https://www.mirareality.com/. [Accessed: 16-Jan-2018].

[34] M. Adcock, B. Thomas, C. Gunn, and R. Smith, "Enabling physical telework with spatial augmented reality," in ACM SIGGRAPH 2014 Posters on - SIGGRAPH '14, 2014, pp. 1–1.