Understanding Farmers' Expectations and Experiences in Using Sensor Technologies

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ABSTRACT

Sensor-enabled tracking technologies have been applied in farming systems to enhance the efficiency by documenting detailed information about farms and making predictions. However, less is known about how farmers make sense of the tracked data and act upon them. Investigating how some Taiwanese farmers respond to a system that monitors those data, this study found that farmers need historical data as well as real-time ones from multiple sources and that it could be challenging for them to make sense of the data to the point that they want to outsource part of their decision-making to the system.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

knowledge transfer, smart farming, prototype, user experience

1 INTRODUCTION

Growth in agriculture is the backbone of a country's economy and vital to sustaining people's lives. How to leverage technologies to improve agricultural practices has started to receive scholarly attention. Computationally, smart agriculture technologies are designed to enable farmers to keep track of various types of data for precise monitoring and control over the crops [3, 7, 15]. Despite the technological improvements, scholars have started to pay attention to the sociotechnical challenges that arise from the technology adoption and deployment processes [12], among which a call for a more user-centered perspective can help better support farmers' practices [10, 11]. For example, with all the data tracked by the sensing technologies, it is less discussed how farmers deal with and make use of the data for intended causes. In an effort to deepen the understanding in this aspect, we conducted a preliminary user

study of five farmers who have been using a monitoring and logging system for their user experience to investigate how they leverage and interpret the data collected. The findings of our study provide an understanding about agricultural informatics and shed lights on future technological designs.

1.1 Supporting Data Tracking on Farm

Innovative technologies have emerged to support agricultural projects so that the farming systems can be more efficient and respectful of the environment [9]. For example, agriculture-centered HCI research proposed designs to support farmers' practices and values [8] or how they can connect and socialize with other farmers for information exchange [13]. Tracking technologies with sensors or IoT (internet of things) tools are used to document detailed information about farms, such as soil, irrigation, weather, crop, and yield to farmers [3, 7, 15]. Other systems propose better and more precise algorithms to help farmers predict yield so that they can improve income [14].

Providing mediated support for agriculture-centered HCI systems raises some challenges. The most significant one is in the smart agriculture systems where different types of data are tracked through various sensing sources, which actually reflect much diversity depending on crops, farming methods or agri-ecosystems [2]. Moreover, there are various types of data to collect on the farm, such as plant growth, fertilizer level, irrigation control, micro-weather around the farm, etc. [3] in order for farmers to make informed decisions and take prompt actions. However, it may demand much knowledge and literacy regarding how to leverage and interpret these data. HCI researchers noticed that farmers' current practices and technology needs were not well supported by the mainstream and industry HCI [10–12]. As key users, it is less discussed how farmers monitor various types of data, make sense of them, and the challenges and unmet needs they face to act on the data.

1.2 Making Sense of Tracked Data

The availability of pervasive computing, mobile/wearable devices, and applications introduces opportunities for users to document biometric and behavioral data anytime and anywhere, such as step counts, heart rate, sleep hours, etc. While data derived from automated tracking with these technologies may be more accurate and standardized, the data recorded can be difficult to interpret and appropriate or the metrics are not personalized or desired enough [16]. Supporting users to make sense of these tracking data has been a major issue in personal informatics literature revolving around health and well-being [17] or technology use [5].

Data accuracy and reactions to errors are important aspects in personal informatics literature because they are suggested to affect

users' engagement and satisfaction with devices [4, 16], which may further affect their health [17]. Similarly with personal informatics, smart agriculture provides various types of data documented on farm. However, it is less discussed how the farmers deal with, make sense of, and act upon the data. We argue that from a user-centered perspective, it is important to contextualize domain-specific informatics in order to understand users' practices and needs. This study intends to complement the prior HCI works by investigating farmers' data tracking and uses for smart agriculture system designs.

As a starting effort to understand the users' actual practice, we decided to examine how farming-related sensing technologies are being used in Taiwan. The research question that guided the current study is: How do Taiwanese farmers perceive and make sense of the smart sensing systems? We found that farmers value historical data as much as, if not more than, the real-time sensing data, which they sometimes have difficulty in interpretation and sense-making. Our finding suggests that it is critical for the data to be user-friendly in the first place, as such friendliness enables further explainability and usage.

2 METHOD

Through snow-ball sampling, we conducted an in-depth interview with five farmers who have been using a real-time monitoring and logging system in their farms to gather their experience in using and making sense of the data collected. This system was developed based on an exploratory interview study that gathered expectations and actual use cases from different stakeholders in agri-food supply chain, including farmers, sellers, customers, and experts in agriculture.

2.1 System Interface

The system interface is divided into two main sections (see Figure 1): the navigation panel, where active projects are listed, and the dashboard, where project-related information, such as the starting and ending dates and summary of farming report, is displayed. By choosing different sections in the navigation panel, the user is able to (1) access the real-time monitoring data of air humidity, sunshine, soil temperature, etc., all of which are updated every five minutes (see Figure 2), (2) set up one's own project for crops and customize the area, cultivation density, and types of produces (see Figure 3), (3) pair the monitoring sensors with a specific project (see Figure 4), and (4) log the farming progress with images and texts, either individually or collaboratively with assistants and other farmers. The farming report, which contains the history of sensing data, logs and notes, as well as the basic information, can be exported and/or viewed as part of the project history. The users are also able to receive notifications and reminders from the system by connecting it to Line, an instant messenger commonly used in Taiwan.

2.2 In-Depth Interview with the Users

We approached five farmers who have been using this system for further feedback. All of the participants were farmers located in Taiwan (four males and one female, 27-39 years old), but with different farming crops. We conducted one-on-one interviews to gather their user experience of the system from 1-3 years of using.
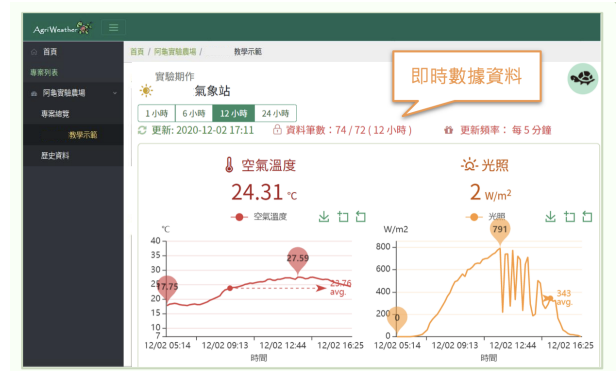

Figure 1: System Interface

Figure 2: Real-Time Sensing Data in Dashboard

The questions pertained to their day-to-day use of the system, the challenges they have encountered, and the improvements they proposed. The interviews were audio-recorded and transcribed into texts. The first and last authors open-coded the data and distilled important themes after refining the codes. In the next section, we present results from the interviews that illustrate critical themes in designing systems for smart farming.

3 RESULTS

The codes emerged from the exploratory interview can be categorized into three salient themes, presented below. For each quote, we also added the gender (M = male, F = female) and age of the participant.

3.1 Taking Historical Data into Account

A repeatedly mentioned insight of using the system is that it should be able to take the historical data into account. Historical data are especially meaningful for farming, as they not only contain patterns and trends valuable for future reference but can also be a point of comparison when needed.

> Sometimes I will refer to the historical data and briefly check what I was doing this time last year and use it to decide if I am about to plant something or do other things. The historical data can also be used to suggest

Figure 3: Setting Up Projects

Figure 4: Pairing Sensors with a Project

what is effective in the past and provide advice for us. (P1, M, 39)

One user suggested historical data could also be economically meaningful, as the farmers can use them to grow the most profitable crop.

> Farmers can be strategic with the historical data. The data are able to tell you what is profitable and when it is best to plant at a specific location. (P4, M, 29)

One user mentioned the historical data should incorporate the farmers' own notes in addition to the sensor data as well.

> I would like to have my own logs as part of the historical data. For instance, I can take notes and photos of how much rain we had this month and annotate how it has affected the quality of my tea. All the critical data related to the quality and its harvest can be presented within one page, so that it is convenient to review over the years. These are very meaningful data for farmers, not unlike those grape yards which use the historical weather data to predict the taste of wine. (P3, M, 35)

In summary, users agree that historical data, whether collected by the sensors or logged by the farmers themselves, can potentially provide valuable insights and experience to aid farmers' decisions.

3.2 Leveraging the Power of AI and Integrating Other Resources

In addition to historical data, users also mentioned more resources could be incorporated using the power of AI. These resources can be hardware and devices, such as drones, and external information and knowledge.

> For instance, sometimes we have pest problems, and what we do now, if we don't recognize what it is, is to take photos of the pest and send them to researchers and experts via Line, so that they can tell us what it is and how to deal with it. The problem is the feedback is usually not immediate enough; we have to wait for them to get back at us. It would be ideal if we could have something like "search by image" and have immediate feedback and know what to do with it. (P2, F, 27)

Drones and other types of knowledge, in addition to the sensor information, could also be applied in smart farming.

> The data and information are still largely scattered at this point. Oftentimes when I am done with the system, I have to refer to Central Weather Bureau to check data of UV lights and wind speed, and sometimes look for the manuals for plans and solutions to deal with pests and questions about fertilizer. The sensor information and the how-to knowledge are still quite separated; it would be ideal if they are integrated together. Additionally, we can use drones and devices like that to calculate the quantity of produces. (P5, M, 39)

In general, users expressed that they wanted a hub that integrate not just real-time information, but contextualized, problem-oriented knowledge as well.

3.3 Making Sense of the Data as well as Decisions for the Users as Different Stakeholders

Some users mentioned that it was hard to interpret the raw data, not to mention using them for their own work.

> It is painstaking to look at the data. Generally farmers wouldn't even look; they would much prefer just sending alerts based on the data. (P1, M, 39)

Some suggested that they would prefer the system take a step further and directly make decisions for the users.

> I don't understand the data and neither do I know how to use them. It would be ideal if the system makes the decision based on the data it collects and informs me when I should, for example, trim, water, or apply fertilizer, or better yet, what fertilizer to use, based on its detection of the soil. (P2, F, 27)

> The alert model it provides should inform me about things like germination stage and irrigation time. For now, I only know if the water is enough but don't know when it should be given at different periods of

the growth process and how much should be given. (P3, M, 35)

Some also mentioned that as other stakeholders may also have access to the data, it will only make sense if they can understand and interpret the data, and ideally, be attracted by some part of them.

> I think for now it seems like a storybook and may be attractive to the consumers who have access to the data. They would be walked through the whole process of farming, much like hearing a story. (P2, F, 27)

In general, users expect the system to be more than just a hub for all the sensor-collected data but somewhat like an agent that is able to make interpretation and sometimes decisions based on the data it has, and based on who it is interacting with.

4   DISCUSSION AND CONCLUSION

Taken together, the three insights gathered from the interviews suggest that farmers expect rich information sources, both historical and real-time, to help them make decisions. From the farmers' own perspectives, our results confirmed previous findings that such information can effectively provide preventive and corrective actions [6]. The findings also enriched the understanding of the specific aspects of such actions could take place and data could contribute to.

However, farmers' craving for richer information sources comes with the prerequisite that the information itself should not be overly complicated to the point that they could not understand it to use it for decision-making. Some expressed that they wanted the system to just tell them when to do what; others requested at least the data can be made sense of. It implies that the user-friendliness of the data is highly prioritized. Apparently farmers have their own mental models of important indicators for their crops, and they feel comfortable if the system can be sufficiently malleable in this respect to cater their needs of taking notes and reviewing historical records to aid their decision-making process.

On the other hand, farmers' suggestion of having the system telling them when to do what merits more discussion. It specifically harks back to the ongoing debate of the responsibility issue in explainable artificial intelligence, that human users need to shoulder the responsibility for AI-assisted decisions and that they will need to have an available explanation for the decision made [1]. While having the system recommending when to do what is an understandable sentiment, future designs should explore how to bring the humans and machines/systems in closer collaboration to reach a mutually agreed-upon decision.

As an exploratory first step in gathering feedback and iterating the system design, we found that farmers value historical data as much as the real-time sensing data, which they sometimes have difficulty in interpretation and sense-making. Our finding highlights the importance of the explainability of the tracked data. In the future, we plan to continue interviewing other stakeholders, including consumers, experts, and sellers, for their feedback to the design.

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