ModBox: Low Power Long Range IoT Modular Sensor Box
(Technical Report)

The Effect of Smart Farming on Decision-Making in Agriculture
(STS Topic)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The Internet of Things (IoT) can be described as the network of every physical device that connects to the internet and can process, store, and communicate data (Clark, 2016). By the end of 2020, the IoT market is expected have 35 billion devices connected, largely due to its capabilities for collecting data and gathering insights (Maayan, 2020). The term "SMART" is an acronym for "Self-Monitoring Analysis and Reporting Technology" and is a marketing term that broadly implies connection to the IoT (Anderson, 2020). IoT has been associated with smart home technology, healthcare, smart cities, and recently has been gaining attention in agriculture. The American Farm Bureau Federation surveyed farmers, and states that "smart farming" can reduce costs for resources by an average of 15% and increase crop yield by an average of 13%. The first recorded instances of IoT implementation within agriculture can be dated back to the 1980s, when a Geographical Information System (GIS) was used to gather geographic data on farmland (Brase, 2005).

Newer technologies that have emerged in recent years within smart farming include smart sensors, climate control, and livestock tracking (IOT Solutions World Congress, 2019). These technologies gather and backhaul large amounts of data, and allow decisions to be made based on predictive analytics. Specifically on farms, a wireless IoT protocol that is becoming more and more prevalent is LPWAN (Low-Power Wide-Area Networks), as it works in areas with poor wireless coverage, extends battery life, and reduces costs (Senet, 2020). IoT and its recent production of sensory big data in farming applications is moving the human decision-making process to be increasingly facilitated by the logic of algorithms (Marquis, 2020). This work will examine the effects of smart technologies on human impact in decision making among different stakeholders, specifically within agriculture.

The technical aspect of this paper covers the development of a use-case agnostic wireless hub that can be used in long range sensory applications. This hub needs to be compatible with a variety of communication protocols as well as wireless protocols in order to maximize its flexibility for different use scenarios.

This paper will also cover the concept of technological momentum, and how IoT, specifically in farming, has progressed in its implementations. It will examine agriculture's transition from farmer controlled decision-making to big data controlled decision-making, and who it has affected.

Low-Power Long-Range IoT Modular Sensor Box

This capstone is focused on designing a modular gateway that should be modifiable for use within various applications in IoT. This project was inspired by Alarm.com, an R&D focused company that provides a cloud-based platform and hardware solutions for home and business automation and security (Alarm.com, 2020). Collaborators include technical advisor Reid Bailey, and technical capstone teammates Yann Kelsen Donastien, Adam El-Sheik, Ethan Staten, Pedro Rodriguez, Joseph Carley, and myself. The building block for this project will be a LPWAN hub to which users can connect multiple sensors through a variety of wireless protocols. LPWANs provide optimal solutions to use cases that require devices to send small amounts of data, such as a sensor's temperature reading, periodically over remote networks that span many miles and use battery-powered devices that need to last many years (Wedd, 2020). A number of LPWAN solutions, such as LoRa, Sigfox, and NB-IOT grew at over 100% over 2019 to reach 231 million global connections (Pasqua, 2020). The ability to inexpensively enable remote sensor monitoring over a greater range has proven to be a valuable and popular addition to the family of IoT solutions, and will be the centerpiece of this project. Due to its increasing popularity and practicality for a wide range of potential use cases, the capstone team will use LPWAN technology protocols with a prototyping focus on Bluetooth, LoRa, and Z-wave Long Range.

LPWAN gateways take considerable time and resources to develop from scratch. Current hub technology in this field has not addressed the issue of interchanging sensors within the hub with minimal engineering work. LPWAN hubs on the market now, such as the Thingenix SensorHUB (Thingenix LLC, 2019) or NB-IOT Sensor HUB (Anciaux, 2019), don't include the proprietary connection protocol that can be used in this device, and aren't designed for being rebuilt with different LPWAN protocols for different industries. The current LPWAN hubs work for a pre-defined set of sensors only, and don't have customizable LPWAN connection protocols outside of the ones they've listed in technical papers. This becomes a problem when multiple industries demand different sensors or connections to be used, that are often proprietary and require only small changes to circuit design.

Due to growing investment from different industries, companies in this space, like Alarm.com, have a need to architect a system of designs that can support a heterogeneous mix of sensors, and feed data into a hub that then does a data backhaul for analytics (Ayaz, Ammad-uddin, Sharif, Aggoune, & Mansour, 2019, pp. 2–3). This hub has a need to use a variety of wireless protocols to connect to servers, different common sensors, and other hubs in order to save development time and resources. The proposed solution will be a hub designed from scratch using a piece meal approach, where we select each individual component within the hub and build a series of reference designs. The overall layout of these reference designs can be seen on a high level in Figure 1. The three interfaces represent the connection from the 3 selected wireless protocols to the CPU, which then will process and send the data to the cloud. The 3 protocols, or radios, will be designed with a plug-and-play approach. This means these components will be able to be replaced and/or re-designed for different sensors or communication needs, and can operate independently of one another. The device will be powered externally for the sake of longevity, cost, and development time. It will have persistent storage to collect data logs, and perform testing and debugging. This system will continue to operate in the event of a temporary external power loss. While the project is centered on completing the designs of a hub, the focus is on the modularity and variability of the hub for more efficient transitions to different use case scenarios. This would solve the problem of time and resource loss due to repeated engineering processes by providing template designs for common industry needs.

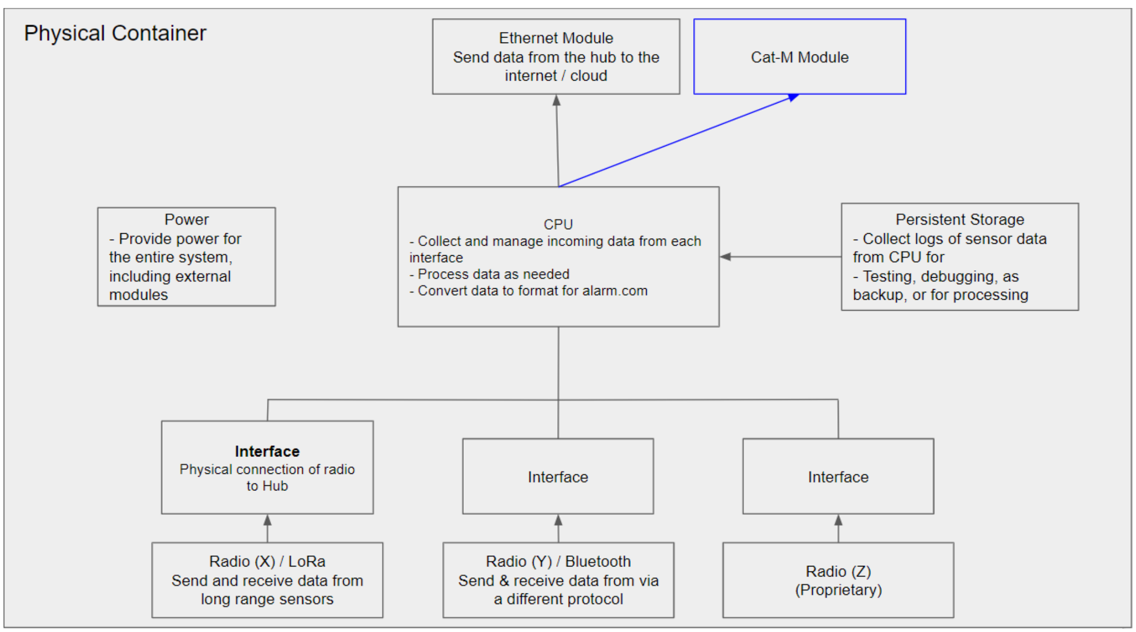

Figure 1. Block Diagram of LPWAN hub design and functionality. (Gunderson et al., 2020)

One of the primary use cases for the hub would be for farms, where it would use various sensors to detect any irregularities in the farm's fields, or provide the data needed for analytical insights on the backend. In the past this would be done through physical inspection, whereas now companies are creating solutions that utilize sensory data to enhance decision making, and blindly trusting the results provided from the data.

Analysis of Technological Momentum in Smart Farming

Technological momentum is a term that can be described as the fusion of social determinism to technological determinism. On a broad scope, social determinism is the idea that people are what they are, or make their decisions, based on social factors that shape their environment (Markman, 2011). Technological determinism, also on a broad scope, is the idea that technology and society are linked in a causative relationship (Hallström, 2020). Thomas Hughes argues that time is a crucial factor in technological momentum as a technology grows from social determinism to technological determinism over time (Hughes, 2000). As technological systems become more complex over time, which in the case of farming is the rapid increase in available data and connected devices, systems tend to be more shaping of society and less shaped by it (Hughes, 1987). Where the farmers have to be careful is with normative technological determinism, if and when the system of smart farming becomes so complex and common that it is no longer amendable to social control (Winner, 1980). Agriculture is becoming more automated, and this can be seen in recent innovations and adoptions in the industry like the hub capstone project. This automation in decision-making is contributing to and leading to a technological system that shapes farming when they may not even realize it.

Technological Determinism persists in the reactions experienced when confronted with new ways of doing things, as seen with new ways of utilizing IoT over the years (Wyatt, 2008). IoT in farming may have caused farmers to feel a sense of relief at a time where food production has a need to increase exponentially. Farmers have gone from the use of simple GIS to understand the land, to nearly fully autonomous farms and predictive analytics, and they've adopted these technologies at alarming rates due to their effectiveness. Over time, farmers are reacting by gaining trust of smart technology's decision-making. A 2020 survey by Purdue University reported that 44% of farmers follow analytics closely, while 53% follow analytics somewhat closely (DeLay, 2020). This use of IoT allows farmers to innovate and progress on a scale never seen before, however, it can be dangerous in many ways if they become over-dependent on the capabilities of data.

As stated before, LPWAN in IoT is a growing market, and in addition to current stakeholders, there are a number of new stakeholders that are attracted to the idea of big data and get support from big tech investors (Wolfert, 2017). With the introduction of new stakeholders and changes in current stakeholder roles, the farmers will be affected in terms of issues with data ownership, data quality, analytics, and changing business models. This investment to big data in agriculture will provide unprecedented decision-making capabilities within the industry, and these decisions may not be up to the farmers themselves. A 2014 survey revealed that over 82% of farmers and ranchers said they were unclear on how companies intended to use their data (American Farm Bureau Federation, 2014). Changes in decision-making not only result from explicit IoT data insights, but can also be taken away from farmers in the form of contractual agreements with tech companies.

Algorithm decisions and farmer decisions are linked in a causal relationship through the usage of IoT on farms. In an article from a precision farming consultant, Ian Beecher-Jones, an overview is provided to farmers who are looking to get into precision agriculture, or smart farming. He argues that the most difficult part of precision agriculture is the human decision making, or deciding what inputs to vary, such as the amount of fertilizer to increase or decrease.

He also argues that, based on his experiences, the process requires human interaction with the interface, but once programmed correctly, can be automated within their given parameters (Beecher-Jones, 2017). However, 47% of farmers don't understand farm data software (DeLay, 2020). It is up to the farmers whether or not they will make the effort to keep up with the technological changes that are inevitably happening to their industry, or if they will take the risks of allowing companies and algorithms to make their decisions for them.

The hub developed in the capstone aspect of this project is a direct consequence of the transition from social determinism to technological determinism associated with IoT data usage over time. As farming becomes more integrated with smart technologies, farmers are gaining efficiency, but losing their decision-making power.

Companies and algorithms are both making decisions for smart farmers as opposed to physical inspection and analysis like it was done in the past. This is representing the growth of IoT in agriculture from social determinism to technological determinism. In order to keep up with the companies and algorithms involved in these solutions, farmers now must educate themselves on the software in these systems and the legal issues involved, or they risk to lose all their decision-making prowess.

Research Question & Methods

The question I will investigate is: How has farmers' impact in agricultural decision making been affected by smart farming, and how will it be affected? This question will allow me to investigate the different stakeholders and technologies that are involved in smart farming that were discussed in this paper. The results will hopefully provide insight as to what IoT solutions may help farmers, and what solutions may hurt them. With the implementation of IoT in farming growing at a rapid rate, farmers may be in immediate danger of losing their independent decision-making. Based on my capstone project's contribution to this, it is necessary for me to research this question from an engineer's perspective and from a social perspective to get a holistic view of the potential benefits and dangers to farmers.

Data from two public surveys given to farmers regarding their involvement and views on smart farming and precision agriculture will provide a consumer perspective. One of these surveys was done by Purdue University, and asks farmers various questions about data privacy with smart farming, farmer education, and making decisions based on analytics. The other survey was published by the University of Guelph, and includes surveys of farmers concerning decision-making changes, stakeholder relations, and trust in the technology with smart farming. To supplement these surveys, three separate case studies offer evidence that cover big data decisions, the learning curve with this technology, and the different trust between stakeholders. These case studies were chosen based on them being issues that are relevant to the decision-making farmers and technology producers, and have all experienced changes with the further use of IoT technologies in farming. This will allow me to understand what decisions are made by which stakeholders, and where the line is drawn as far as those who bear the risk and those who control the risk.

The data will be analyzed by comparing the survey results to the case studies, and seeing if the data matches the different real-world examples in agriculture. The ultimate goal is comparing and tracing the producers to the farmer, to find how each stakeholder interacts. This allows me to analyze the farmer perspective, and how they make decisions based on both technology changes, and the producer choices that affect said technology changes.

Conclusion

Smart farming has created a need to gather and analyze data, where in the past it was not needed to be successful in agriculture. This has caused a problem where farmer decision-making risks being out of their control, and in the control of algorithms and tech companies. The solution that my capstone team is working on is a modular LPWAN sensor hub that can be used in a variety of industries without complete product redesign. This solution has the potential to further this loss of control, unless farmers can begin to understand the software and legal issues that are affecting them. By the end of this research analysis, there will be more visible insight as to the impact that IoT had and will have on the various stakeholders' decision-making power within the field. Ideally if they can understand this, then farmers can make the decision on their own as to whether or not IoT solutions will provide benefits that outweigh risks, and make the most of the real benefits. Increasing their understanding will also grant them more control over these solutions, and in turn their own decision-making.

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