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Cloud-based Decision Support and Automation for Precision Agriculture in Orchards

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Abstract:

Recent technological and commercial developments make cloud computing an affordable, scalable, and highly-available platform technology. Meanwhile, precision agriculture is showing its potentials by improving agricultural operations through better data-driven decision making. Nevertheless, further development of precision agriculture requires better technology and tools to process data efficiently at a reasonable cost, and to translate the data to better decisions and actions in a field. We developed a framework for cloud-based Decision Support and Automation systems that can acquire data from various sources, synthesize application-specific decisions, and control field devices from the Cloud. A distinctive feature of our framework is its extensible software architecture: decision modules can be added and/or configured for a specific operation. The platform features a device-agnostic frontend that can process incoming data in different formats and semantics. Finally, the platform incorporates software-defined control, a new software design paradigm we proposed to enable versatile and safe control of field devices from a cloud computing platform. An early version of the system has been developed and tested with support from the USDA.

Key words: cloud computing, decision support and automation, precision agriculture, software-defined control.

1. Introduction

Precision agriculture is a site-specific farming practice that uses technologies to measure and respond to inter and intra-field variability in crops. It has been seen as a critical tool for increasing agricultural productivity while preserving natural resources. The "brain" of precision agriculture is a decision support system (DSS) that helps a grower process and respond to intra- and inter-field data. With recent technological advances, particularly sensors technology and online data services, agriculture is increasingly becoming a data-rich operation. Particularly specialty crop industry in US is going through a transformation through the use of information technology. By the USDA definition, specialty crops are "fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops (including floriculture)." Specialty crops are responsible for half of the gate value of US agricultural output [1]. Compared with commodity crops, special crops are more site-specific and labor-intensive. It is sensitive to variation in field, labor situation, and many other factors. Whereas many agriculture operations can use a decision support system, specialty crops particularly may benefit from a better decision support system, as a majority of orchards today still follow a traditional human-centric decision process.

Developing a better decision support system for specialty-crop industry presents some specific challenges in information technology. Specialty-crop operations are highly seasonal. Requests for decision support can fluctuate drastically on- and off-seasons. One challenge is *how to meet the fluctuating demands while still providing highly available services*. Moreover, each orchard has its own unique operation characteristic. Another challenge is *how to develop a decision support system that can be reconfigured for a specific operation*. Finally, a precision agriculture operation is a close-loop control system, with inputs (e.g. sensors and other data sources) from a field and feedbacks (e.g. field actions) to the field. A traditional decision support system emphasizes only on the first part of the control loop, that is, taking inputs and synthesizing decisions. A grand challenge is *how to close the control loop by controlling field devices safely with optimized decisions.*

According to the official NIST definition, cloud computing is "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*"[2]. Cloud computing is inspired by a utility delivery

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model: computing powers may be delivered on demand just like electricity or gas, in an effort to meet demands for scalable, highly-available, and economical Internet-connected computing resources. A cloud computing service enables users to request and release resources on demand, and to pay for only what has been used. By pooling resources together, a cloud computing service generally has a higher availability than traditional user-operated server networks.

Cloud computing is particularly beneficial for decision support in precision agriculture for specialty crops. First, precision agriculture in an orchard is a data-rich operation. A decision support system needs to handle a large volume of data from sensors and other sources. Cloud computing provides scalability necessary for handling these data in real time. Second, the demand for decision support fluctuates greatly on- and off-seasons. Through resource provisioning [3], cloud computing can change quickly the number of server instances and other resources, based on the demand. Finally, agriculture decision support systems are increasingly hosted on Internet, to take advantage of internet-connected devices (Internet of things[4]) and to build an online community. A cloud service provider handles the complexity of running hardware and maintaining middleware for enhanced availability and security. This leaves developers to focusing on the logics of a web-based decision support system.

Moving towards cloud-based decision support presents opportunities as well as new challenges. First, precision agriculture uses a variety of sensors and data sources, each of which may have its own data format and semantics. A cloud-based decision support system needs to handle a diversified profile of data types and formats; second, traditionally a decision support system is application-specific. A farmer may need to access different systems for a specific application (e.g. irrigation, fertilization, etc). To provide a streamlined user experience, a cloud-based decision support system shall be able to be extended and configured for different applications; and finally, recent development of Internet of Things (IoT) links field devices through Internet. To capitalize the progress in IoT, a future decision support system is expected to control field device safely from the cloud.

In this paper we discuss our framework for cloud-based decision support and automation systems (DSAS), and our experience of implementing it in Agrilaxy, a DSAS we developed from ground up to take advantage of the scalability and availability of a cloud computing platform. We developed new techniques to address the design challenges faced by a cloud-based DSAS. The rest of the paper will be organized as follows: Section 2 gives an overview of our framework. In Section 3 we discuss its device-agnostic data importation frontend, which works with different data sources with custom-defined data format and semantics. In Section 4 we discuss its extensible software architecture for decision modules. In Section 5 we introduce *Software-Defined Control* paradigm, a new software design paradigm for controlling physical devices in a field from the cloud. Section 6 discusses the current implementation of Agrilaxy, Finally, Section 7 concludes this paper.

Figure 1 Cloud-based decision support & automation system: an overview