

Sustainable Agriculture through ICT innovation

**Autogenic Mobile Computing Technologies in Agriculture:
Applications and Sensor Networking for Smart Phones and Tablets**J. Welte¹, A. Ault², C. Bowman², A. Layton², S. Noel¹, J. Krogmeier², D. Buckmaster¹¹Agricultural & Biological Engineering, Purdue University, 225 S. University St. West Lafayette, IN, United States. ²Electrical & Computer Engineering, Purdue University, West Lafayette, IN, United States.
jwelte@purdue.edu**ABSTRACT**

No two farms are the same with respect to management structure, equipment, farm plan, etc. Farm information management systems (FMIS) of the future need to accommodate the differences and be holistic in nature as well as cost effective. Fortunately, many technologies are available to address these concerns, but they need to be integrated into workable systems which are intuitive as well as reliable. This manuscript covers some elements of developing autogenic systems (automatically generating data) which use always-on public cloud storage servers and highly capable mobile devices in concert with current agricultural equipment sensors and technologies. This type of system can provide nearly continuous and seamless synchrony and data sharing among devices for functionality and should improve data mining possibilities in the future.

Keywords: User-centered, Data management, Mobile apps, Cloud storage, ISOBUS, United States of America

1. INTRODUCTION

As modern agriculture works toward the goal of doubling food production by 2050, it has become clear that an information-based approach is needed to maximize efficiency with limited resources. Since no two farms are the same with respect to information communication and management structure, a specialized farm management information system (FMIS) which is tailored to the realities on the ground of individual farms is likely to be more effective than generalized FMIS available today. An FMIS which incorporates low-cost, widely available mobile computing technologies, internet-based cloud storage services, and user-centered interface design principles has the potential to provide such a solution. In addition, as the amount of information to be managed grows, more data will need to be provided *autogenically*: that is, created with semantic meaning without the need for manual human input.

1.1 Background

Most American farmers who adopt new technology tend to be among the largest operations in terms of acres cultivated and revenues generated (Diekmann and Batte, J. Welte, A. Ault, C. Bowman, A. Layton, S. Noel, J. Krogmeier, D. Buckmaster. "Autogenic Mobile Computing Technologies in Agriculture: Applications and Sensor Networking for Smart Phones and Tablets". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013. The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the International Commission of Agricultural and Biosystems Engineering (CIGR) and of the EFITA association, and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by CIGR editorial committees; therefore, they are not to be presented as refereed publications.

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2010). Fountas et al. (2005) surveyed farmers in the eastern corn belt of the United States and Denmark and found that the most important impediments to precision farming implementation were the time requirement, lack of technical knowledge, and cost. Whipker and Akridge (2009), while examining technology issues that create a barrier to expansion/growth in precision agriculture, identified costs and hardware/software incompatibility as the most significant hurdles to adoption. Diekmann and Batte (2010) point out that while reducing input costs was identified as the greatest motivator for adoption of precision farming technology, nearly 80% of respondents also identified the ability to gather better information for decision making as a motivator to adopt.

Precision agriculture technology suppliers have advertised adoption benefits over the last two decades including more informed decision-making, increased farm operation efficiency, awareness of environmental impact, and enhanced recordkeeping. However, the most common issues cited with current technology solutions are those concerning data handling and compatibility, leaving the majority of available data unutilized. Current data management solutions often fail to provide a user interface that allows the farmer to make informed decisions.

1.2 Literature Review

Developing and using GPS-enabled systems to document field operations and generate as-applied data sets was one focus of research in the 1990s (Morris et al., 1999). The initial motivations for documenting application operations were the desire for enhanced recordkeeping and generating proof of regulatory compliance. It then followed that such extensive geo-referenced data sets could be analyzed (“mined”) to provide information to improve the efficiency and effectiveness of in-field machine operations. Crisler et al (2002 a, b), Ess (2003), Grisso et al (2004), and Adamchuk et al (2011) have demonstrated techniques for extracting machinery management information from geo-referenced data files. This information could then be used by the farm manager to alter field-working techniques or reassign machines in such a way as to improve operational efficiency and productivity of machine and human assets. Industry is just beginning to offer hardware and software packages to capture and share field operations data, e.g. AGCOMMAND from AGCO (AGCOMMAND, 2013), and FarmSight from Deere (John Deere FarmSight, 2013).

A study of Swedish precision farmers confirmed the need for a user-centered farm information system in information- and technology-intensive farms. Following this, L. Pesonen, et al., gave recommendations and guidelines for a novel, intelligent, integrated information and decision support framework for planting and control of mobile working units. After system validation and extensive analysis, they concluded that information management systems in mobile plant production environments should be internet-based with an open interface, and that farm data saved in a central database should be accessible to the farmer through internet servers (Pesonen, et al., 2008).

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Sustainable Agriculture through ICT innovation**2. SPECIALIZED AUTOGENIC FMIS**

Modern advances in mobile devices and cloud storage have begun to change the picture of FMIS from being closed, expensive, and unwieldy to open, cost-effective, and mobile. To that end, we discuss here aspects of a specialized FMIS, which is capable of using these technologies to adapt to differences among farms.

2.1 Mobile Devices

Smart phones, tablets and their associated applications (apps) have transformed how people communicate and go about daily business. Modern agriculture needs to capitalize on these capabilities to significantly improve the process of data collection and analysis. By integrating sensors already on agricultural equipment with wireless technologies, the full potential of using cloud-based data mining to drive sophisticated graphical analysis can be achieved at near zero marginal cost.

2.2 Cloud Storage Services

A useful FMIS makes data available wherever and whenever it is needed. This need for always-on availability was traditionally out of reach for most farmers because they do not have the resources to maintain their own Information Technology (IT) department to handle server maintenance, upgrades, backups, and security. Solving these particular issues is precisely why consumer-grade, file-based cloud services such as Box, Dropbox, Google Drive, Trello, CloudOn, and others have become so popular in recent years. These services give farmers the ability to have their data anywhere for a fraction of the cost of handling data in-house. No other industry relies on the antiquated method of transferring data between data cards and flash storage -- neither should agriculture.

Most information used for the kind of farm management decisions which occur daily in the field does not require access to large amounts of data. Data-intensive maps of yield, crop moisture, fuel usage, plant population, etc. may look nice, but are relatively useless for making the sort of daily decisions which require mobility. For example, farmers need to know which fields remain to chisel plow this season as they contemplate where to work each day. All that is needed is a list of field names or a map of field boundaries that are marked “done” and “not done”, rather than point data. This sort of aggregate, high-level information is easily stored, updated, and accessed via standard consumer cloud storage.

As FMIS progress from simply storing and retrieving data for management decisions into full-fledged data mining engines, agriculture-specific cloud storage systems will be required to deal with both the large amounts of data and the intensive processing necessary to reach statistical conclusions.

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2.3 Data Sources

The key to any autogenic FMIS is access to data. Fortunately, useful data already exists in many forms within a typical agriculture production system. Understanding this variety of sources is necessary to enable specialization of an FMIS within a farm.

2.3.1 Manual Input

The simplest method of data collection is manual input. This traditionally consists of handwritten notes made with pen and paper. Long, standardized forms tend to overwhelm the operator if particular attention is not paid to the user experience. Providing simple, specialized apps for a variety of data entry tasks is crucial to getting standardized, minable data into the cloud where it can be put to use. Most people will not use mobile devices for data entry if such a switch entails more work, higher learning curves, and longer entry times than their existing system. Therefore, each data collection task should be automated to the extent possible. By making data entry faster and simpler than pen and paper, data in the cloud will be both more complete and more correct than inaccessible stacks of paper notebooks. Examples of manual data entry include: recording field, operator, rate, and tank number as anhydrous ammonia is applied, recording chemical mix, field, and date that a pesticide was applied, and recording seed variety, fertilizer, and area during planting.

2.3.2 Internet-based: Weather, Geospatial Information

Many types of useful information for FMIS are already publicly available online. However, accessing this data is sometimes quite difficult due to a lack of application programming interfaces (API), and a general lack of data format standards. Despite these issues, any FMIS which can utilize data which does not need to be manually collected will exponentially increase its ability to provide useful analysis.

Some examples of useful data available within the United States include:

- **Weather Data:** Provided by the National Weather Service Advanced Hydrologic Service (<http://water.weather.gov/precip/download.php>). Daily, monthly, and yearly precipitation amounts are available going as far back as 2005. The data are derived from a combination of radar and rain gauge measurements.
- **Soil data:** Available from the USDA NRCS Web Soil Survey (<http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>). It consists of geolocated polygons representing the survey map units, and tabular data with soil attributes to which the polygons are referenced.
- **LiDAR Elevations:** This extremely precise elevation data is available from the Open Topography project (<http://www.opentopography.org>). Most LiDAR data has a nominal resolution of 1.5 meters or less, and will eventually cover much of the land in the US and around the world.

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2.3.3 Machine Information

Almost all machines and implements involved in modern production agriculture have sensors that are critical to machine operations and automation and can also create useful data in real-time during operation. Some examples include: vehicle location, seed population, chemical application rates, wheel slip, fuel usage, crop yield, crop moisture, PTO status, hydraulic remote actions, and many others. The proprietary, non-standard nature of these machine sensors has traditionally limited their usefulness due to an inability for outside systems to access them. As compliance with the ISO11783 communications standard has progressed, this hurdle is reduced.

Inexpensive, wireless networks of sensors using Bluetooth for communication would enable smart phones to collect data that is not tied to a particular proprietary source. While Bluetooth is not the ideal communications platform for sensor networking generally, it is inexpensive and widely implemented in smart phones. Sensors with relatively low data rates, such as ID tags and contact sensors can be easily retrofitted on existing machines and implements to provide information to autogenic algorithms.

2.4 ISOBlue

In response to the great promise of machine-level sensor data being available in the cloud, we have launched the ISOBlue project (<http://www.isoblue.org>). The project aims to create a completely open source, inexpensive means for getting data from any ISO11783-compliant tractor to a Bluetooth-equipped mobile device in real-time. The mobile device can then upload the data to the cloud over its existing cellular connection. Enabling farmers and researchers to access, analyze, and store their own data will vastly improve the ability of precision agriculture technologies to finally reach their long-awaited potential of using statistical data mining techniques to optimize many features of agricultural production from yield to environmental impact.

2.5 Specialized FMIS Apps

The fundamental reason why farmers cannot use their data is actually quite simple: the interfaces necessary to achieve their goals either do not exist, or are too complex to be realistically useful. Modern software engineering techniques, improved UI design practices, highly-capable mobile devices, and cloud-based storage services have the potential to close the gap between data collection and utilization. One user-focused design pattern concentrates on task-specific apps running on mobile devices synchronized to a cloud service. Location, personnel, machinery, and agronomic data will be stored and synchronized across all users in a farming operation in near real time.

2.5.1 User-centric Interface Design Practices

The key determinant of successful acceptance is the extent to which the interface helps users accomplish specific tasks faster, simpler, and more efficiently. Adapting some of

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the principles of Agile Software Development, typical users should be grouped by common characteristics and explicitly described through an example persona of each group. These hypothetical users should be given names to personalize them, and their descriptions should include personal characteristics, motives, job roles, etc. Specific user stories then compliment the user descriptions by describing the real-world situations where these people will use the interfaces being designed. User stories can include details of a specific activity such as a job description, environmental considerations including distractions or hazards, desired interface behavior, anticipated problems, etc. User interface designers benefit from the ability to imagine realistic people using the product when determining the appropriateness of the solution (Spolsky, 2000).

In the case of FMIS, we have identified a representative set of users to be:

- Farm Owner Fred: Generally older, more technology averse, and very conservative. Fred has the final say in most planning and purchasing decisions.
- Manager Michael: Generally younger, adept at new technologies, and is usually the first to suggest new changes to the operation. Any FMIS will likely be introduced to the farm through Mike, and therefore Mike will be responsible for making it run properly.
- Farm Hand Hank: A normal employee at the farm. By virtue of his position as primary operator, Hank is the person who will interact with an FMIS the most. However, Hank has the least control over purchasing and implementation decisions for the farm.

Each of these stakeholders interact with the FMIS in different ways due to variations in their perspectives of operational and management tasks.

2.5.2 Specialized, Task-specific Apps

Since each app is intended to perform a specific task that solves a specific problem, these individual apps can provide a much simpler interface than currently available, total data management solution approaches. This approach makes FMIS economically feasible for smaller farms, a group where the costly, total data management solution approach was difficult to scale down. Such a system would allow farmers to collect, protect, manage, and own their data without the need to pay subscription fees or purchase costly devices.

The real power of these specialized apps comes in their ability to autogenically infer data with semantic meaning. Since their scope is intentionally limited, they have a much higher likelihood of success at correctly inferring semantic meaning without human input. For example, a tillage app might have a simple task: given a list of fields, keep track of which ones are planned, in progress, or done. Manual human input can of course be used for this, but it is also possible to analyze a GPS path for when a tractor with an attached tillage implement enters a field and starts driving around at slow, relatively constant speeds. An autogenic system would then mark that field as “in

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progress.” When that tractor leaves the field entirely, if it has already driven around most of the field, it is likely safe to mark that field as done.

The diagram in Figure 1 represents an example system architecture from the user’s perspective. This approach allows the farms to put together a data management system to meet their particular needs. Thus, the system architecture would likely be different for every farm.

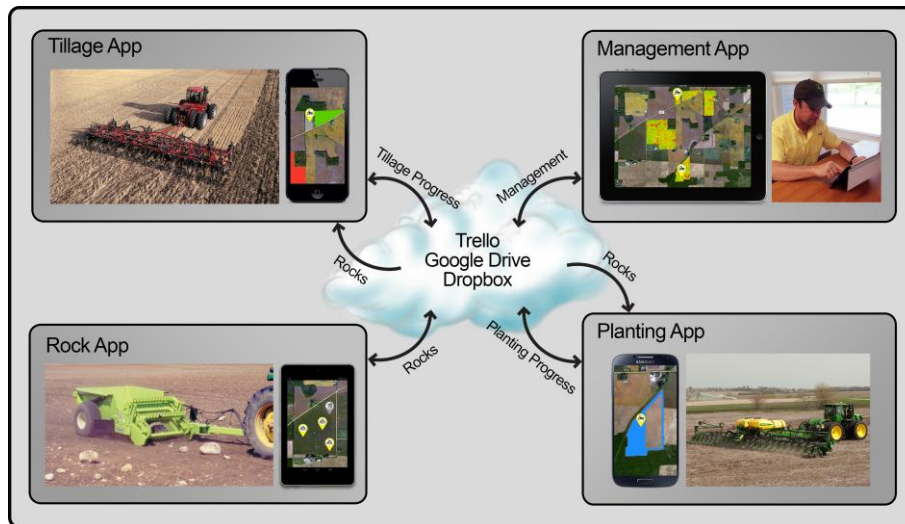


Figure 1: Example system architecture with task-specific apps sharing data through cloud storage

3. CONCLUSIONS

While the technology of precision agriculture has progressed far in recent years, the capabilities of farm information management systems have lagged behind. A new approach which enables and utilizes

- specialization for individual farms,
- autogenic data recording to maximize available data and minimize human error,
- widespread adoption through user-focused design practices,
- always-on availability through the cloud,
- hybrid sensor networks which can effectively deliver data to the cloud,
- and non-proprietary open source efforts such as ISOBlue

can help to close this gap. Such systems will allow the use of the statistical data mining techniques necessary to improve production agriculture in the future.

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