An Approach to Farm Management Information Systems Using Task-Specific, Collaborative Mobile Apps and Cloud Storage Services

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Abstract. Modern production agriculture is beginning to advance beyond deterministic, scheduled operations between relatively few people to larger scale, information-driven efficiency in order to respond to the challenges of field variability and meet the needs of a growing population. Since no two farms are the same with respect to information 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. This paper presents the design and implementation of a novel distributed set of open-source, collaborative mobile apps known as Open Ag Toolkit (OpenATK). OpenATK endeavors to provide such a specialized FMIS solution by incorporating low-cost, widely available mobile computing technologies, internet-based cloud storage services, and user-centered design principles.

Keywords. Data Management, Mobile Apps, Cloud Storage, Usability, Distributed Data Model.

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1. Background

Precision agriculture technology has advertised adoption benefits over the last two decades including more informed decision-making, increased farm operation efficiency, awareness of environmental impact, and enhanced recordkeeping (Bleicher, 2013). However, the most common issues cited with current technology solutions are those concerning data handling and compatibility, leaving the majority of available data unutilized.

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).

Current data management solutions often fail to provide a user interface that allows the farmer to make informed decisions (Welte et al., 2013). In our experience, farmers have expressed frustration with implementing currently available options. We think this frustration stems from a lack of focus on the user experience with regards to farm management, and because of the proprietary nature of the equipment, it is difficult for third-parties to produce integrated farm management solutions.

1.1. Data Storage and Sharing

A useful FMIS should make data available wherever and whenever it is needed. This need for secure, 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. The standard method in precision agriculture of transferring data between data cards and flash storage is unique to the agriculture industry – agriculture could learn from the progress made by other industries (Welte et al., 2013).

In a traditional farm setting, there are various pieces of equipment operating in different locations, and keeping the farm management system updated with data for each piece of equipment is inconvenient for timely data management. Cloud storage has the capability to solve problems with limited on-site storage, remote monitoring locations, mobile data sources, and real-time data access (Snyder, 2013). Several agriculture-specific solutions are beginning to appear in the marketplace including FarmLogs, John Deere’s FarmSight, Trimble’s Connected Farm, and AGCO’s AGCOMMAND.

1.2. Designing for Usability

A key determinant of successful acceptance by intended users is the extent to which the interface helps them accomplish specific tasks faster, simpler, and more efficiently. The simplicity by which a design does this is known as usability (Nielsen, 2001). Various procedures for designing usable software have become somewhat standard in recent years.

One such standard procedure is the writing of functional specifications. Functional specifications document how a program will function from the perspective of its users. This
method of communicating design decisions facilitates the iterative nature of product design. Functional specifications describe product features and the user’s interactions without deep consideration of implementation. Functional specifications differ from technical specifications in that they describe how a product will work solely from the user’s perspective. Technical specifications then consider the internal implementation of the program which is specified by the functional specifications (Heap, 2013).

An important section of the functional specifications describes imaginary, stereotypical users. User descriptions should include personal characteristics, motives, job roles, etc. User interface designers benefit from the ability to imagine real people using the product when determining the appropriateness of the solution (Spolsky, 2000).

User stories compliment the user descriptions by describing the real-world situations where people use the software being designed. User stories can include details of a specific activity such as a job description, environmental considerations such as distractions or hazards, desired interface behavior, anticipated problems, psychological state of the user, etc. (Spolsky, 2000). A variety of stories should be constructed to cover as many specific conditions as possible. Explicit details about the activity provide a clearer picture for user interface (UI) designers when considering variations of interface design. Details should include a description of the farming task being completed with attention to the user’s surroundings which often impose limits on the user’s attention to the interface. Examples of common farming distractions include operating equipment at night or in standing crops, monitoring other devices in the cab, and others.

User interface mock-ups afford product designers the ability to iterate the interface designs more rapidly than more formal representations. UI design often starts with hand sketching the screen layouts to visualize the interface with a paper model. Interface design tools such as Balsamiq Mockups (Balsamiq, 2013) often incorporate software to provide image libraries for designers to drag-and-drop onto a template device. This method of producing UI mock-ups allows designers to generate and reproduce interfaces quickly while maintaining proper and consistent size proportions. The interfaces are verified with the user stories by visualizing each user holding the device and walking through the screens to complete common farming tasks.

2. Objectives

Our primary goal is to provide farmers with tools that enable them to collect and manage data for their farms easily and efficiently. Our approach is to create a set of task-specific mobile apps that can share machine, field, operator, and other data among themselves and automatically synchronize across all people on a farm through existing cloud storage services. Using cloud storage services should facilitate cross-platform compatibility allowing mobile devices to collect and edit data; this will also allow desktop computers to access and analyze larger data sets.

3. Methods

We have launched the Open Ag Toolkit (OpenATK) project to provide farmers with the information they need when they need it, without becoming locked into expensive, obfuscated proprietary systems (OpenATK, 2013). Data should be accessible and understandable outside the apps themselves to better facilitate true data ownership by the farmer. The hope is that focusing on very task-specific apps will lead to better, more intuitive designs that are likely to be of interest on many farms. This approach will also help keep the
learning curve low for other developers and farmers who may wish to contribute to the project whenever a new use case arises.

The OpenATK model is novel in several respects:

- Use of existing (sometimes free) cloud storage: this dramatically lowers the startup cost to farmers, many of whom may already be using one of these services.
- Non-binary formats: data is always represented in human-readable form in the backend. Great care goes into designing the storage format in ways that farmers would naturally have chosen themselves in the absence of the app. It should be quite simple for farmers to correct any errors that may occur over time. Each app is therefore designed to be highly tolerant of errors in backend data formats which might result from inadvertent modifications.
- Task-specific, user-centered design: by limiting each app to solving one particular problem, simple usage scenarios for real people can be used to help ensure that each final app is intuitive to actual human beings. The primary design goal of each app is for people unfamiliar with the app to be able to use it without the need for a user manual. For developers, this allows them to design their app completely independently of other apps for their particular task, and then add in collaboration only where it makes sense to do so.
- Collaboration among apps: To simplify the distributed data model, each piece of information within the entire suite of OpenATK apps has a unique parent app which is solely responsible for its storage and retrieval. If App A needs data that App B is responsible for, A will request it from B. If B does not exist on the mobile device, then A is designed to fill the data void intuitively until which time a user may decide that App B would be useful.
- No required apps: many FMIS systems require a farm to modify their internal operations in order to fit the predefined FMIS model. The OpenATK approach allows people to use any combination of apps that they find beneficial. For example, the Tillage App records the name of the operator who performed tillage. However, a “People Manager” app may be uniquely responsible for handling information about people on a farm and sharing it across many apps. If a particular farm only uses the Tillage app and no other apps, they have no reason to use the People Manager app. Therefore, until a People Manager app is installed, the Tillage app simply maintains a list of possible operator names.
- Embracing Heterogeneity: since many apps can be written to solve the same task, there is no need for one app to work for all farms in the world. Some farms may find a general Planting App useful, whereas other farms may find a Peanut Planting app suits their needs better.

For OpenATK, the anticipated user groups were identified, named, and described in detail with regard to characteristics, motives, and roles within the management structure. Representative situations involving these users were clearly described through user stories which provided a better mental picture when designing the UI. Interfaces were then mocked up prior to developing code and tested against the user stories. An example functional specification for the OpenATK Tillage App is located in the appendix.
3.1. User Groups and Stories

Often, defined job descriptions do not exist on a typical farm because individual workers have a variety of roles. For this reason, users were separated into three groups and then classified as primary or secondary users. The user groups as they have been defined are upper management, middle management, and farm worker. The upper management user is typically in the farm owner position, whether the owner is a single person or a group of individuals. This user is responsible for decisions on the farm operation level, such as seasonal planting rotations, purchasing, etc. The middle management user is typically an experienced employee who is responsible for day-to-day decisions, such as allocation of human and equipment resources, training employees, coordinating maintenance schedules, etc. The farm worker user is considered any employee who performs general labor.

It is not uncommon for farm employees who hold management positions to also perform labor similar to that of a farm worker. It is important to group the users based on their major role on the farm and understand that farm employees fulfill a variety of roles. Depending on the size of the farm operation, a single individual could be responsible for the yearly planning, the day-to-day decisions, and portions of the general labor.

Users are classified as primary or secondary based on their interaction with the app. The primary users are directly interacting with the mobile device by recording data or using the information from the app to make decisions. An example of a primary user is an equipment operator recording field operation information with the Tillage App. The secondary users are indirectly using the app to complete an activity. An example of a secondary user is a farm manager using information entered by the farm worker to make a management decision. The app should be designed with the primary user in mind with consideration for interactions with the secondary user.

These general descriptions of users tend to be useful in getting a high-level picture, but they fail to allow the user interface designers to put themselves in the shoes of real people. To accomplish this, an imaginary person is created who would belong to each user group. This person is given a name which identifies them, and their name is used for all discussions and user stories. While this person does not fully represent every single person that could ever belong to that user category, the danger of leaving out this step is that the software will be designed for “user categories” rather than flesh-and-blood people. Plenty of virtual people will use the software but no actual ones will.

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

- **Farm Owner Fred**: Generally older, more averse to technology, and very conservative. Fred has the final say in most planning and purchasing decisions.
- **Manager Mike**: 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.

3.2. UI Mockups

The following figures show example UI mockups for the OpenATK Tillage App. The purpose of this app is to track progress for various forms of tillage throughout a season. Figure 1
walks through the most common use of the Tillage App where the equipment operator completes a tillage operation and changes the status of the field from “Planned” to “Done”. The entire process requires only two touch activities: 1) selecting the field and 2) selecting the correct status.

![Tillage App UI mockup of the most common use scenario. User selects a field and changes the operation status.](image1)

However, the number of touch activities can be reduced to a single action if the app infers certain information about the situation. By analyzing the GPS location of the phone and observing its location in a field marked as “Planned”, the app can accurately infer that the equipment operator is likely completing the planned tillage operation in Field 4. Thus, the UI simply asks the user if they have completed the operation, which can be confirmed by a touch and hold on the screen. Figure 2 demonstrates how the situation is handled if the equipment operator is in a field which is not marked as “Done.”

![Tillage App UI mockup demonstrating how the common use scenario can be simplified by inferring certain contextual information about the situation.](image2)
While the map view provides a quick view to see the fields and their respective status, a list view provides a more efficient means to display summary information and more complete operation information. Figure 3 shows the proposed Tillage App list view where the user will find operational summaries and a list of the fields grouped by operation status in expandable lists. By selecting a single list item the UI is able show the user more in-depth information such as operation details, comments and operation analysis.

3.3. System Architecture

The system architecture should be viewed from both the user’s and developer’s perspective. While the developer must be concerned with the data structure and management, these system details should be transparent to the user. The diagram in Figure 4 represents an example system architecture from the user’s perspective using four different devices on the farm. Note how the user is only presented with the UI they need and the required information is retrieved from cloud storage. 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 (Welte et al., 2013).

Figure 3: Tillage App mockups showing how to navigate to a detailed view of an operation summary from the list view.

Figure 4: View of the system architecture from the perspective of four different devices on the farm.
The developer must be aware of the system details such as local libraries, sharing permissions, data format, and others. The diagram in Figure 5 represents the system architecture for the developer’s perspective.

![Figure 5: View of the system architecture from the perspective of the system developer.](image)

Each piece of data has one parent app which is responsible for its Create, Read, Update, and Delete (CRUD) operations. Other apps on the same device should request data from its parent app if available, or use an app-specific means of providing data should the parent app not exist on the device. To synchronize a particular app’s data across devices, a general synchronization library transforms the local, app-specific data into the format best suited to the chosen type of cloud storage. For example, the Rock App synchronization process to Trello treats each rock as a Trello card that resides in either a “Picked Up” or “Not Picked Up” list. The library synchronizes any activity on Trello to the local Rock App database, and vice-versa.

### 3.3.1. Local Sharing Between Apps

In order to provide flexibly from a user’s perspective, relevant data from each app can be shared between apps on a device, and shared with other devices on the farm using cloud storage. Initially, each app shares its data locally with any app that requests it. On Android this is accomplished using content providers to SQLite databases. This allows each individual app to supply read or write access for its data to all other apps that request it which have been identified as valid OpenATK apps.

Data can also be shared with other devices on the farm. Shared libraries can be written to provide data syncing capabilities to a variety of cloud storage services including Trello, Google Drive, Dropbox and others. Each app implements app-specific extensions to these shared libraries to allow cloud storage of important data. From a user’s perspective, cloud syncing is controlled by a corresponding cloud storage app. Each cloud storage app allows the user to input their credentials to the service and control which apps sync to this service. Necessary cloud storage authentication information is shared on Android through a content
provider from the cloud storage app to any apps that use the corresponding shared library to sync data. This allows any app to sync to any cloud storage service and eliminates the necessity for a user to reenter authentication information into each individual app.

3.3.2. Sharing Between Devices: Cloud Storage and Authentication

By using existing cloud storage services, the complex task of sharing and authentication can be offloaded from the small-scale developer or technology-savvy farmer. Cloud storage providers generally use protocols such as OAuth in order for apps to acquire tokens needed to access a data. In this way, apps can simply synchronize their data to the cloud storage service for whichever user is currently logged in, eliminating the need for a separate server which maintains logins, passwords, and sharing permissions.

Consider the case where Manager Mike is logged in to Google Drive on a particular device, and the Rock App is syncing its data to a file in a shared folder. If Farm Hand Hank now logs in to Google Drive on the device, and Hank has the same shared folder, the app will now sync data through Hank’s account. Since data is shared within the same farm, switching users will not trigger a full-scale synchronization task because the data will look the same from every user’s perspective. Only when one device switches between different farming operations will data need to be synchronized in full.

3.4. Trello

Trello is a free cloud storage service specialized to organize collaborative lists. The novel organization structure is immediately understood by virtually anyone because it resembles a board covered in note cards. This organization method is an intuitive combination of free-form and structured lists. It represents a number of individual items or tasks on cards which are grouped vertically into lists. One or more lists are then placed onto boards. Cards can easily be prioritized by moving them up and down within a list, or be moved between lists on a board. User accounts can be attached to cards to show who is working on which task. When an individual card is selected in the Trello interface, the back of the card shows deeper information including card description, file attachments, checklists, labels, due date, and activity thread. Trello can be accessed via the web or through apps on mobile devices (Fall Creek Software, 2013).

Trello’s biggest advantage is its ability to provide backend storage which makes sense to the common person (Ault et al., 2013). The design of the Open Ag Toolkit utilizes Trello as one possible backend cloud storage service for its mobile apps. The app design process aims to match the elements in the app with elements in Trello as one-to-one in order to help users intuitively understand how changes to their Trello board affect the app. Each app has its own board which it shares its name.

For example, the OpenATK Tillage App uses a Trello board titled “OpenATK - Tillage”. There are corresponding lists for each type of tillage listed in the app: e.g. the “Chisel 2012” mode uses a Trello list titled “Chisel 2012”. Adding a new list to Trello will cause a new tillage mode to be available in the app. Each Trello card represents one field for a particular tillage operation as “Planned”, “Started,” or “Done.” Fields that do not have cards listed for a particular tillage mode have a default status of “Not Planned.” In order to maintain the list of fields and field properties such as acreage and boundaries, a special list in Trello titled “Settings” can be used to store field information and other items specific to the app. Figure 6 shows an example Trello board for the Tillage App. Note how each card represents a single tillage operation with the front of the card showing the field name, operation date and operator name.
Trello provides a feature to give individual cards colored labels which can each be given a name, such as Planned, Started, Done, etc. Trello also has a feature to filter cards based on text, label, due date, and others. The Tillage board can be filtered by label to include only cards which have the label “Planned” or “Started” to give the user a quick and easy method to see what tasks remain incomplete.

Figure 7 shows the back of a card from the Disc 2012 list in the Tillage App board. Note how the app organizes other tillage information into the card description.
4. Initial Open ATK Apps

The initial design process has focused on a data management system of collaborative mobile apps with a decentralized data model utilizing cloud-based storage services. Each app is intended to perform a specific task that solves a specific problem relating to an operation such as tillage, planting, or spraying. Where applicable, each task can be simplified in the future with automated data collection by interfacing the apps to peripheral devices, externally available data sources, and sensors through a standard ISOBUS. This system will allow farmers to collect, protect, manage, and own their data without the need to pay expensive subscription fees or purchase costly devices.

4.1. Tillage App

As discussed in previous sections, the Tillage App provides a simple means of managing data pertaining to tillage operations. Currently, this app keeps a record of tillage operations for a list of fields with statuses of “Planned”, “Started”, or “Done”. Also, each record contains the date of last status change, the name of the operator, and comments. Each field also has an optional associated boundary polygon which is shaded according to the operation status. Figure 8 shows a screenshot of the UI in a typical use scenario. Four fields are saved in the Tillage App with one field marked as Planned, one marked as Started, one marked as Done, and one without any operation planned or completed with the Not Planned label.

Currently, all data is manually entered by a member of the farm organization. Future versions will incorporate methods to analyze GPS data to determine when a tractor with a tillage implement enters the field and starts driving in the field at a slow, relatively constant speed. When the app observes these operation parameters, it will automatically mark the operation status as “Started”. When the app observes that the equipment has exited a field after it covered the entire field, the operation status will automatically be marked as “Done”.

![Figure 8: Screenshot of the Tillage App UI in a typical use scenario. The 31.5 acre Field 4 is selected and the menu allows the operator to record the date the operation was completed, his/her name, and any comments about the operation.](image-url)
4.2. Planting App

The task of the Planting App, similar to the Tillage App, is to record information during planting season, and make those records available whenever they are needed. The initial version of the Planting App is a web app which runs in-browser using Javascript and caches data locally via the HTML5 storage API. The local cache is synced with Trello using the same algorithm as the OpenATK Trello library in Android.

As shown in Figure 8, the Planting App provides a simple means of cataloguing relevant information after an operator finishes planting a field. A manager can use the Trello board itself to revisit past records as the growing season progresses. A full functional specification is planned for this app, at which time it will be transformed into an Android app optimized for the three OpenATK representative users, similar to the Tillage App.

Figure 9: Screenshot of Planting web app. The Planting App is used to record relevant information after planting a field. This information can be easily recalled by looking at the Planting board in Trello.

Figure 10 shows an example Planting App Trello board. The board is organized with lists for Bean Planting operations, Bean Varieties, Corn Planting operations, Corn Varieties, and Web Controls. The operation lists provide a record of planting operations for the farm. The varieties lists expedite the recordkeeping process by attaching pictures of the seed properties rather than requiring the user to input each piece of information (Ault et al., 2013).
Figure 10: Example Trello board containing planting records from Ault farm for 2013. These were all entered by the operator using an iPhone or iPad while in each field.

4.3. Rock App

The Rock App provides a UI to easily mark the location of rocks for removal. When an operator marks a rock, its location is shared with other devices on the farm using cloud storage so that it can be removed quickly. Another operator is likely responsible for the removal of the rock, and marks it as “Picked Up” once it has been removed. The location of rocks can also be shared with other apps where appropriate. An example of another app which would benefit from knowing the location of rocks in a field would be the Tillage App. An operator should be shown the location of rocks in a field before a rock causes damage to an implement.

Figure 11 shows the Rock App UI with rocks marked in a field. Rocks can be added to any location and moved on the map regardless of the user’s location. When a rock icon is selected, the menu allows the user to mark the rock as “picked up”, attach a picture and add a comment. As the map view is zoomed out, the rocks are grouped together with nearby rocks and a number icon appears indicating how many rocks are grouped together.
Figure 11: Screenshot of the Rock App UI showing five rocks marked for removal and four rocks marked as picked up.

Figure 12 shows the Rocks Trello board with a card for each rock on the appropriate list, “Rocks In Field” or “Rocks Picked Up”.

Figure 12: Screenshot of the Rock App Trello board with an individual card for each rock; five on the “Rocks In Field” list and four on the “Rocks Picked Up” list.
4.4. Trello App

The Trello App is allows the user to specify which OpenATK apps will synchronize with Trello. The app is responsible for retrieving and providing Trello authentication information to any other app which requests it through the use of a content provider. For a farm without a pre-existing Trello organization, the Trello App assists the user with setting up the farm organization and selecting members.

4.5. Tractor Ballast Calculator App

The Tractor Ballast Calculator App is designed to improve work efficiency, tire wear, fuel consumption, and horsepower transfer by properly balancing weighted loads on the tractor’s frame. Farmers regularly set up a tractor to pull a particular implement and rarely adjust ballast if the tractor is used for a different task. Reasons cited for neglecting ballast weight adjustment include lack of equipment to verify changes, difficulty moving weights, and misunderstanding of the benefits of properly ballasted tractors.

In keeping with the OpenATK practice of making apps as simple as possible, this app does not require cloud synchronization or local sharing to accomplish its task. Therefore, it acts as a simple calculation tool in order to help promote its use among users with a wide variety of skill levels.

Figure 13 shows the Tractor Ballast Calculator UI which asks the user to input four simple pieces of information and gives the static weight distribution, total tractor weight, and the weight to power ratio (Taylor et al., 1991).

![Figure 13: Screenshot of the Tractor Ballast Calculator App showing the results for a 150 hp tractor with front wheel assist pulling a semi-mounted implement at 5.5 mph.](image-url)
4.6. Water Plane App

The Water Plane App, shown in Figure 14 is a surveying tool for visualizing elevation data in the field when planning underground tile locations or troubleshooting water issues. It simulates a level plane of water rising and falling above and below the surface of the ground to visualize the relative elevation of one area to another as a user moves the slider bar at the bottom of the screen. As the water plane is raised above the ground surface elevation of a pixel, it is colored blue (i.e. covered with water). This is extremely useful for quickly locating the highest and lowest points in a landscape, or determining if a remote location is above or below another location.

The user copies digital elevation model (DEM) files to their mobile device’s local storage. Such files are freely available in high resolutions from the Open Topography website (OpenTopography, 2013). When the app is opened, outlines of all DEM files available on the device’s storage card are displayed on the map, ready to be selected for use. Live markers can be added to the overlay to specific locations. The markers show the distance above or below the user’s GPS location as they walk around.

![Figure 14: User interface for the Water Plane App. Areas outlined in red indicate available DEM maps on the local storage card for that location. Areas colored blue are below the “water plane” reference elevation. Moving the slider at the bottom will raise and lower the water plane’s elevation. The red marker shows the relative elevation difference and linear distance from the device’s current location.](image)

4.7. Future Work

The first release of task-specific, collaborative mobile apps and the open source libraries necessary for anyone to create apps using the OpenATK model are available from the
OpenATK website. User feedback will direct future work as we continue to design and develop mobile apps. Initial work will focus on the development of more apps, including:

- **Field Notebook App**: an app for managing field information such as name, boundaries, hazards, problem areas, and other notes about a field. These will be available to other field operation apps. Once the Field Notebook App is installed on a device, each field operation app will no longer be responsible for its own fields list. It will also provide the interface to view field data as overlays from field operation apps.

- **Equipment Notebook App**: an app for managing equipment information such as equipment model, maintenance schedules, part numbers, etc. Similar to the Field Notebook App, this app will share equipment names with other apps to simplify the recordkeeping process.

- **Spraying App**: similar to the Tillage and Planting Apps, this app will track progress in application of pesticides and fungicides during the growing season. It will also simplify the task of recording mandatory pesticide application information.

- **Harvesting App**: this app is still in the initial design phases, and may incorporate a device such as ISOBlue (ISOBlue, 2013) for gathering yield information, or simply allow a user to take a quick picture of an existing yield map on a proprietary monitor or desktop application which can then be interpreted algorithmically.

- **Manure App**: this app will aid in tracking manure application to fields using manure samples, sizes of hauling equipment, and GPS paths. The app can recommend adjustments to application rate or driving speed in real time to maintain desired levels of fertility or abide by setback rules from features such as surface water inlets or roads.

Once a usable set of OpenATK apps has stabilized, the next phase of the project is to automate data collection as much as possible. Experiments will be performed to analyze common GPS paths to infer information, incorporate external data sources such as soil type maps and weather, and interface with on-board sensors via the ISOBlue open source device.

5. Conclusion

The progression toward information-driven agriculture necessitates an approach to FMIS which can adapt to different farming operations and provide farmers with long-term ownership of their data. This paper presented the start of the OpenATK project which endeavors to provide such a solution using

- existing cloud storage services,
- human-readable data formats,
- a distributed data model,
- and task-specific, collaborative mobile apps.

The collection of apps allows each farm to put together a highly usable, tailored data management solution to improve production agriculture in the future.

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Appendix

Functional Specifications for the Precision Agriculture Tillage Application

1.0 OVERVIEW/MISSION

The purpose of the Precision Agricultural Tillage App is to provide a simple means of automatically recording data pertaining to tillage operations and displaying feedback to the users. The data collected will be used for easy recording of tillage operations for both short- and long-term planning.

2.0 HYPOTHETICAL USER GROUPS

2.1 Farm Owner Fred

Fred is the family farm owner and has lived on the family farm since childhood. Fred has been the leader of the farm for 10 years when he inherited the farm from his father who farmed the same 250 acres till the day of his passing. Fred grew up in a family with three other siblings, all girls. As the oldest sibling and the only boy, he elected to forego higher education to return to the farm and help his father provide for the family. Fred is now 68 years of age; husband of 45 years; and father of five children. After the passing of his father he aggressively acquired more land as it became available within a reasonable distance from the original farm. He has reluctantly adopted new farming practices and management styles when the pressures of the larger farm forced him to adapt. With the last acquisition of land, the farm has surpassed the 2000 acre mark. As the need for larger equipment increased, he has purchased several used tractors and implements and leases a new combine from a local dealer.

Fred’s spends approximately 50-60% of his time working on the farm, and the rest of the time in the farm office where he oversees farm operations, seasonal planning, and purchasing. His lifetime of experiences and countless lessons from his father have taught him that his intuition is almost always correct. He prefers the tried-and-true, proven methods of farming and management. He is skeptical of the idea of integrating technology into his farming operation because past experiences with new technology have lead him to believe the time commitment and costs are too large to warrant his continued interest. He lacks the technical and mechanical skills to use the technology effectively, and until a couple years ago he was unaware of precision farming technology.

Recently he attended a trade show where new precision farming technology was one of the featured innovations. After watching the demonstrations and talking with some long time farming friends, they agree the opportunity is there to reduce input costs and positively aid the decision making process. However, without the formal training, many of them feel the large time commitment is too great for the risk of frustration. For them, it has to work the first time and every time after that or they will abandon it for the proven methods.

2.2 Farm Manager Michael

Michael is the 40-year-old son of Fred. Although Michael was raised on the family farm, after high school, he left home for college and received a bachelors degree in mechanical engineering. During his time at college he found the love of his life and his dream job. Following graduation he moved to the suburbs of a city near the family farm where he settled down working for an engineering consulting company and started a family. After working in industry for six years, his grandfather’s health began to decline and his father’s role on the
farm became more important. At the age of 28, he quit his job at the consulting firm, relocated the family near the farm, and took a job working for his father and grandfather with the intent to assume a middle management position.

Michael is currently the manager for human and equipment resources. In this role, which answers directly to his father, he oversees the allocation of workers and equipment to complete all farming operations. He spends roughly 80-90% of his time outside of the office and often assumes various roles to assist operations including but not limited to: equipment maintenance and operation, and seasonal planning. His education and industry experiences have taught him that a respected and successful manager must stay involved in all aspects of the operation. Michael enjoys every minute of his job and is committed to the future success of the family farm.

Michael’s education training and industry experiences have proved the value of emerging technologies for data management. He understands most technologies are generalized for the largest market but with a little time and testing, they can be adapted to fit many useful situations. Unlike his father, he believes incorporating precision agriculture technologies are necessary to increase profit and make better informed decisions about short- and long-term planning. In his current position on the farm he is able to work directly with the other equipment operators who will be the primary users of the technology to collect data. His father has taken the approach where he lets Michael test new technologies and he’ll consider it more when Michael has done the legwork to get it started and can prove its worth. Fred does not care if it succeeds or fails as long as it does not cause too much hassle for him.

2.3 Farm Hand Hank

Hank is a non-family employee on the farm. He has been a lifelong resident of the local farming community where he has lived for 27 years. After graduating high school, he passed on higher education because he did not feel it was a good fit for him. Prior to coming to work for Fred two years ago, he worked for a different local farmer for six years which unfortunately ended due to management issues. He was drawn to work for Fred and Michael because he values the family aspect of the management and their commitment to expansion and responsible farming.

Hank is a general equipment operator under the management of Michael. He spends 95-100% of his time in the field or on the road. His tasks vary with the seasonal operations to include tillage, grain hauling, and equipment maintenance.

Hank is the primary user of the tillage app because he is most likely to be the user who is collecting the tillage data from the field. His relaxed and casual attitude toward decision making can occasionally lead to neglecting proper data recording which causes tension between Hank and management. Often, Michael is able to make necessary adjustments or corrections to Hank’s records before they make it to Fred’s desk.

3.0 USER STORIES

3.1 Hank uses the Tillage App to record a chisel operation for a new field

One fall afternoon, Hank receives instructions to chisel plow Field 4 from Michael. When Hank gets to the field he opens the Tillage App, taps “Tillage” (the default mode) and selects “Chisel” from the drop down navigation in the top left of the action bar. He sees the map view, but does not find the field boundary and operation plan for Field 4. He taps the action bar icon to add a new field which opens the boundary drawing function on the map view. He selects the boundary points on the map, taps the check mark in the bottom left of the screen
and sees the field outline and menu slide up on the screen. The app generates a field name and estimates the size based on boundary coordinates. The new field defaults to “Done” which he appropriately changes to “In Progress” and is given that day’s date. If this was Hank’s first time using the Tillage App he would have to manually input his name into the “Operator” entry field. This entry would be cached for future use. He can optionally add comments or a photo, or edit any information from the menu.

3.2 Hank uses the Tillage App to record a tillage operation for a field previously planned

Hank receives a text message from Michael instructing him to chisel plow Field 4. He opens the Tillage App and sees the red boundary of Field 4 on the map view. After completing the planned chisel operation, Hank taps the polygon for Field 4 which brings up the menu from the bottom of the screen. He appropriately changes the status from “Planned” to “Done” which changes the polygon from red to green. He accepts the changes by selecting the check mark icon in the bottom left of the menu or tapping anywhere on the map.

3.3 Fred and Michael use the Tillage App to plan spring tillage operations

During a meeting in the fall, Fred and Michael open the Tillage App to plan fields for spring tillage. Michael taps the drop down navigation from the action bar and adds a new mode “Spring Planting Prep”. He sees a gray polygon any field previously used in the Tillage App or any field available from the Fields Manager App. For each field they would like prepared for spring planting, he selects and changes the status to “Planned” which changes the polygon from gray to red. Additionally, he can assign the operation to a particular employee by inputting an operator’s name.

3.4 Michael uses the Tillage App to plan the day’s operations

Michael begins a late fall morning by opening the Tillage App to see how many fields remain to be chiseled. He taps the list icon in the action bar which displays the field information in an expandable, vertical list. He sees the summary information at the top of the screen which says 247 acres remain which have been planned for chiseling. He taps the single field, Field 5, in the “In Progress” list which flips the list item over to show more information, including the field’s location. To get a more clear picture of the location relative to other fields which need to be completed he taps the map icon on the Field 5 card. This displays the map view and zooms to Field 5. Using the appropriate “zoom out” motions, he finds three more fields near Field 5, and instructs Hank to finish Field 5 before beginning the three nearby fields.

4.0 ANTICIPATED ISSUES

- Cellular connection issues
- Incomplete or inconsistent data input from user
- GPS signal quality
- Sections of fields intentionally left untilled
- User forgetting to open the app before tillage begins
- User forgetting to press start/stop during the operation
- User forgets to changed cached information
- Multitasking users
- Phone call/text interruptions
- Multiple phones in same field/equipment
- Switch user in the middle of a task
- Field Boundaries and Farm Plan... both? one? neither?
• Drawing field boundary polygons
• Contour or Strip Farming styles
• Cross mobile OS platform compatibility

5.0 USER INTERFACE (UI) DESIGN

The figures below show the UI in both the map and list views. The UI mockups have been designed using the web-based software Balsamiq.

6.0 EXAMPLE FIRST TIME USE SITUATION

The figure below walks through how a user would begin to use the Tillage App, what we’ll call the “First Time Use Situation”. The user needs to immediately understand the UI and feel comfortable using the app. If the learning curve is too high or the user becomes frustrated, they are unlikely to open the app again to use it. For this reason, particular attention must given to the user experience for the first time use situation. The map view and icons have been selected to give the first time user immediate comfort and control.

The user will open the Tillage App to find a map view similar to other internet mapping websites. The icons are placed on the Android action bar according to the Android
development files. The user will find an icon to add a new field, an icon to move the map to their location, an icon to control map overlays, an icon to switch to the list view, and the default icon for action bar overflow.

The user will select the [+] to add a new field which will open the field drawing mode. In this mode the user can select polygon vertices to draw the field boundary. After accepting the polygon, the field boundary will appear on the map view and the menu bar will slide up from the bottom of the screen. The menu bar contains entry fields for the information associated with the tillage operation such as field name and size, operation status, date and operator name.

7.0 NON-GOALS AND FUTURE FEATURES

Upon completion of the Tillage App, the technology could be applied to planting operations, turf and golf course maintenance, and lawn care contractors. From research in mobile device applications, it is understood that several, specific function apps are more useful than a single app intended to do everything. There are many farming tasks which require the transmission of data to management and/or other workers. To maximize functionality of this
app, it would need to generate data for other devices and apps, as well as be able to utilize data generated from other devices and apps. The app should work as part of a suite of agriculture specific apps, each designed to help complete a specific task. It will also need to be individually useful if the farm management decides to adopt this technology slowly.