Structure, Features, and Benefits of the Open Ag Toolkit Approach to Farm Management Information Systems

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Abstract.
The Open Ag Toolkit (OpenATK) project was started to help farmers manage and take ownership of their farm’s data, and subsequently reuse information specific to their farm to improve decision making on a daily basis. Some farmers want to get their farm’s data out of the pocket notebooks, office binders, and various other locations into the cloud where it can be securely stored and shared with other stakeholders. In order to facilitate these goals, developers applied various user-focused design practices that led to a suite of collaborative apps with simple, flat user interfaces. The OpenATK approach to a farm management information system uses task-specific, collaborative mobile apps integrated with cloud storage services and a distributed data model to help farmers manage their operation in the mobile settings of modern production agriculture. These Android apps are available for free on the Google Play Store.

Keywords. Data Management, Mobile Apps, Cloud Storage, Distributed Data Model, Field Work

Introduction

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 the generalized FMIS available today. A refined and integrated 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. There are also significant opportunities for the products proposed herein to be accessible to smaller farmers who are not yet taking advantage of the benefits offered by precision farming technologies (Welte, et al., 2014).

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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 (Welte, et al., 2013 b.).

Consumer-grade mobile devices, especially smartphones, are commonplace and possess more computing power than was used in sending the first spaceships into orbit. It seems logical to capitalize on this technology and utilize this mobile computing power to solve agricultural challenges, given that most farm management is done in a mobile setting away from and office or desktop computer.

The overall goal of this research was to design, build, and evaluate an open-source suite of specialized, collaborative mobile applications (apps), cloud-based storage, and existing cellular data networks for record keeping and data management in agriculture. This paper covers the structure, features, and benefits of the Open Ag Toolkit apps.

**Background**

Operating an agricultural enterprise requires managers to make and implement numerous decisions across the operation throughout the season, and many times, away from the office. Managers must process the necessary data in terms of recording, conditioning, and correlating (Sindir, 2006). These decision-makers also use information from a variety of resources, but the most valuable is often the source with information specific to the farm’s operations, which often includes financial and operation records (Sindir, 2006). FMIS can be designed to deal with these issues and to support strategic and operational decisions (Nurkka, et al., 2007).

Murakami et al. (2007) recommended an open software platform as an appropriate solution rather than a single proprietary system because it is unlikely that any single complex and comprehensive solution could meet all the users’ needs.

When considering the core tasks of farm recordkeeping software, Pesonen et al. (2008) identified the following steps when focusing on managing field operations:

- Creating the operation plan
- Delivering detailed task plan to the field
- Setting up mobile working units to execute the plan
- Managing, controlling and recording the operation
- Documenting the as-applied operation for recordkeeping

In recognizing the various information sources, Pesonen et al. (2008) stated that these various sources needed to be easily integrated and combined for different analyses.

**Structure**

While a centralized database model was easier to visualize and has some advantages, a single database would need to contain all of the information a farm needs. This sort of database will be different for different farming operations. It is more efficient to utilize database structures that already exist and are professionally maintained. The OpenATK (Open Ag Toolkit, 2013) apps communicate with the databases through the use of APIs over an internet connection. One benefit of the decentralized data model is that it allows farmers to use whatever cloud storage services they deem most appropriate. Another benefit is that it allows one app to make a change to its database without affecting the rest of the system. The same things might not be true if the OpenATK approach used a centralized data model. The diagram in Figure 1 represents the system architecture with a distributed data model from the developer’s perspective. The lines represent connections from the devices to the individual databases through the use of application programming interfaces (APIs) and an internet connection. Some lines are unidirectional indicating that the apps are only retrieving data from the database. Other lines are bidirectional indicating the apps are retrieving and saving data to these databases. Again, this approach allows the farms and their related service partners to find a tailored data management system to meet their particular needs, and the system architecture would likely be slightly different for each farm.
Figure 1: View of a possible system architecture with a distributed data model from the developer’s perspective. The lines represent connections from the devices to the individual databases through the use of APIs and an internet connection (Welte, 2014).

Features

Murakami et al. (2007) noted that a simple user interface (UI) was an important requirement when designing an FMIS. More specifically, Haapala et al. (2006) concluded that the information presentation and consistency with UI components was critical. They recommended that only information necessary to carry out a task should be presented to the user, and information needed to be presented in a logical order. They also recommended that icons should be designed to be intuitive for first-time users. They found that inconsistency, lack of clarity, and poor choice in icons and language were likely sources of usability problems (Haapala, et al., 2006).

The OpenATK model’s focus on simple, task-specific software led to the creation of a suite of apps. The recordkeeping focused on capturing the answers to the questions “who”, “what”, “when”, “where”, and “how”. Consistency in interfaces between apps helps users feel instantly familiar with a new app and reduces the time necessary to become proficient in their usage. Figure 2 shows how interface components were reused through the collection of apps. Mock ups were constructed using the Balsamiq web app (Balsamiq, 2013).
Figure 2: UI components are reused throughout OpenATK apps, Planting App (left) and Spraying App (right), to give the user an immediate feeling of familiarity when using a new app (Welte, 2014).

The action bar was implemented according to the Google Developer API Guide (Google, 2014 a.). The app icon is located on the far left to give the user a sense of location. The operation type label is just to the right of the icon, and it provides the answer to the “what” question. This label is a drop-down menu with functionality to let the user switch between operation types within an app. Some examples of operation types that a user may define in the Planting App include “Corn 2013”, “Beans 2013”, “Wheat 2014”, and others which are flexible to allow for customization.

The action bar is the preferred location for action item buttons that are consistent throughout the UI. In addition to the app icon and operation type drop-down menu, the three action item icons located on the action bar in Figure 3, include, from left to right, “add new field”, “move map to user’s location” (if a GPS location is available), and “change the map view to the list view”. The icon that is three stacked dots is the action overflow icon, which is consistent with other Android apps. All action items icons that either don’t fit on the action bar or are programmatically assigned there will appear in a drop-down list if that icon is selected.

Figure 3: An example action bar used in the OpenATK Planting App mockups. The items on the action bar, from left to right, are the app icon, operation type drop-down list, add new field, move map to user’s location, switch to list view, and action overflow (Welte, 2014).

The Google Maps interface, Figure 4, is used to provide the base image for UI and gives location context to the user. The Google Maps interface was implemented according to the Google Developer API v2 guide (Google, 2014 b.).
The field operation menu, Figure 5, gives the user an efficient means to note the important details pertaining to field operation records. It provides the “who”, “when” and “where” details for the operation record. The details are easily corrected which facilitates both predictive and reactive scheduling. This menu slides up from the bottom of the screen and is only visible when a field is selected. The field name and size appears on the top row of the menu that corresponds to the field selected. The bottom row holds the date, operation status (Red for “Planned”, Yellow for “Started”, and Green for “Done”), and a drop-down list for the operator’s name.

Some users might prefer to keep more detailed records of field operations. The region-based record, shown in Figure 6, provides the functionality to take more detailed notes and document any variability in the operation across the field. This section captures the details for “how” an operation was completed. The region-based record is divided into two note sections. The top section is more structured with text boxes for operation specific notes. The example in Figure 6, from the Planting App mockups, contains a drop down menu for selecting the type of seed planted and notes about that particular seed type. The ability to take a picture of the seed bag tag proved to be a quick and useful way to accurately record the seed information. This functionality is available by tapping the camera icon. A thumbnail picture of the tag replaces the camera icon after an image is captured.

The second part of the region-based record is an unstructured note area to accommodate any type or length of note entered by the user.
Many recordkeeping tools currently available try to apply the same note template to every field operation, and even if the note template is specialized for a particular field operation the entry fields do not fit every situation that arises in a typical growing season. The OpenATK approach is to allow the user the ability to take completely unstructured notes so that the UI does not become a burden to the user. The text entry interface can suggest note fields with predictive text. For example, if an operator types “Refuge…” in the note area on Field 4, and when the operator starts to type a note for another field starting with “R” the text entry interface would suggest “Refuge”. This suggestion could be accepted by the user through various responses with the interface.

These UI components were developed in a library so that future app development will be able to easily recreate the same look and functionality. This will also facilitate UI updates across the collection of apps because any change in the library will be reflected in the individual apps using the library.

Current work

A review of the original Tillage App – Now the Field Work App

Artificial records for a farm were created to determine if currently available technologies were capable of handling the amount of data generated by a farm throughout the year. After entering the artificial data for the data usage test, the Android OS settings reported that the Tillage App was storing 260 kilobytes locally. For comparison, just one minute of an MP3 music file is approximately one megabyte, which is almost four times larger. The amount of actual data associated with these records is minuscule. The 260kb of stored data fell into three groups: operators list, fields list (field boundary definitions), and operational data. The field boundaries were the largest contributor to the amount of the data generated in the app’s local storage. This is because field boundaries are stored as a list of comma separated latitude and longitude coordinate values to fourteen decimal places. The shape of the fields has a huge impact on the amount of data generated. For example, a single 404 ha (1,000 acre) triangle would only have three latitude and longitude coordinate values. However, the fields used for the simulation in northwestern Indiana were often defined by waterways and roads, and thus, some of the fields boundaries were defined by more than 50 points (Welte, 2014).

Based on feedback from users, the OpenATK Tillage App was renamed and repurposed as the OpenATK Field Work App. This change emphasizes the importance of using terminology familiar to the farmers (Welte, 2014). Along with the typical field work operations such as fall chiseling and spring disking, this also presented the opportunity to use the app to cover a wider range of simple field operations including mowing, baling, chopping, and others.

Trello Sync App

The Trello (Fall Creek Software, 2013) Sync app is solely responsible for keeping the local database and the cloud storage synced. An update is triggered five seconds after detecting a change in a local database. It also looks for updates in cloud storage sync that need to be pulled down to update the local app database. It checks the cloud storage for changes since its last local database sync at least every 30 seconds in case another user has updated the cloud storage but no local change occurred to trigger the sync function. Users of the Trello Sync App can disable automatic updates if they are concerned about battery or data usage. However, if it does not find an update from the Trello website the data usage would amount to approximately 50 bytes per attempt. This would amount to approximately four megabytes/month, or the amount of data to download a four minute
This manual check for an update of the cloud storage is necessary because the Trello API does not currently support the push function for mobile devices. This feature, which is currently available on web app and the native Trello app, would push updates in the cloud storage to all users, and thus, eliminate the need for the apps to manually check for updates.

**OpenATK Shapefile Importer**

Based on internal testing, the original and only method of adding field boundaries to the apps was rather slow and tedious for oddly-shaped fields when the user attempts to accurately draw the field. While the field boundaries could be added over time, many farms already have their field boundaries in other software, often in the Esri Shapefile format. The initial OpenATK FMIS lacked the functionality to import these existing field boundaries into the apps or Trello cards.

The OpenATK Shapefile Importer, Figure 7, will be a web app with the ability to import Shapefiles into Trello where the user's field boundaries are stored for their use in OpenATK apps. Shapefiles drawn with more precise input devices in other software can make for more accurate field boundaries. The primary advantage to this is that if the user has a lot of fields, he can simply import the Shapefile boundaries all at once rather than spend the time to draw each individual field.

![Draft Shapefile Importer UI shown in an intended use situation. The user has uploaded five fields and has selected three of them to import into Trello as cards.](image)

Many large farming operations have custom field boundaries that were created by another service provider in order to utilize product recommendations, soil testing data, and more. The OpenATK Shapefile Importer is unique in that enables the user to utilize their existing field boundaries in the OpenATK FMIS suite of apps.

**Spraying App**

The OpenATK Spraying App is an Android app that assist users in quickly making and keeping track of spraying operations in an “as applied” context. It saves all of the record information locally, and with the
implementation of the Trello Sync App, in the cloud for easy access from other internet-connected devices. This ensures that data is never lost, and is easy to access by those with correct permissions.

The Spraying App uses the familiar Google Map aerial imagery displaying the user’s fields and gives them the ability to keep records of spraying activities on each field. When the user selects a field, they then can add a record for their spraying activity. These records stack on top of each other to create a history of the fields spraying information. The user has the ability to scroll down through the field history to see when the fields were sprayed or any other reason they would need to see spraying history. Additionally, the app has ability to generate reports to enable the user to quickly export his spraying data in a comma separated value (CSV) format so it can be easily loaded into spreadsheet software. This will greatly speed up the record keeping process by taking field information and keeping track of “who” applied “what” mix “where” for each spraying activity. The data can be exported to a spreadsheet for record keeping or, in the case of a custom sprayer, they could modify the data for billing purposes. See Figure 8 for the draft user interface.

![Figure 8: Draft Spraying App UI shown in an intended use situation. The user is adding a new record to the 2014 Corn list for a fungicide application planned for that day.](image)

The Spraying App has a very simple input process using prepopulated menu choices and can be used on the go. It keeps track of the mixes, rate, time/date, and operator all while helping the operator stay focused on the task.
Future Work

Integrating New Data Sources

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. FMIS which can utilize data which does not need to be manually collected will greatly facilitate adoption and increase its ability to provide useful analysis.

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

- **Weather Data:** Provided by the National Weather Service Advanced Hydrologic Service (National Weather Service, 2013). 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. Other weather data of interest could include temperature and wind speed.

- **Soil data:** Available from the USDA NRCS Web Soil Survey (USDA Natural Resources Conservation Service, 2013). It consists of geo-located polygons representing the survey map units, and tabular data with soil attributes to which the polygons are referenced.

- **Light Detection and Ranging (LiDAR) Elevation data:** This extremely precise, remote-sensed elevation data is available from the Open Topography project (OpenTopography, 2013). Most LiDAR data has a horizontal resolution of 1.5 meters or less, but only 28% of the United States excluding Alaska was covered as of 2011 (National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center, 2012). Potential issues with this high resolution data include data conditioning and delivering specific data sets to mobile devices (Noel, 2014).

- **Common Land Units (CLU):** "A Common Land Unit (CLU) is the smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner and a common producer in agricultural land associated with USDA farm programs. CLU boundaries are delineated from relatively permanent features such as fence lines, roads, and/or waterways". CLU borders are available to Farm Service Agency, Natural Resource Conservation Service, and Rural Development employees through the USDA Geospatial Data Gateway (USDA Farm Service Agency, 2013). CLU borders for the majority of the United States are available from AgriData, Inc. through their Surety software with a paid subscription. “Due to Section 1619 of the 2008 Farm Bill the CLU borders are in Surety and Surety Pro are dated May of 2008” (Chad, 2013). Often, field manager software utilizes CLUs to help users get started quickly. In some cases these boundaries are not an accurate representation of how the field is actually managed. For example, a user may find that a large field is actually a group of several small CLUs, or a single, large CLU is subdivided and managed separately. This is often due to CLU boundaries being produced by potentially outdated information.

- **Cropland Data Layer (CDL):** This remotely sensed georeferenced raster data depicts detailed information on crop and non-crop land use to explore land-cover and land-use change in the contiguous United States (Han, et al., 2014). This spatial data is available through the CropScape (USDA National Agricultural Statistics Services, 2014) web application for visualization and download.

Farm Manager Dashboard Web App

Many farmers are comfortable with using office computers to get a “dashboard” or summary view of everything happening on the farm or to complete more complex tasks similar to verifying management decisions. An OpenATK dashboard webpage would be the ideal solution for these tasks because it would be accessible through a web browser on any internet-connected device such as the office computer. The office computers benefit from the larger screens and more precise input devices such as a mouse and keyboard, and many farmers already use office computers to manage farm information. Aggregating the information across all the OpenATK mobile apps in one location will allow the farmer to drill down through the many layers he may create throughout the growing season. The possibilities are endless when considering the future of precision agriculture where a farmer will have access to a multitude of information specific to his operation. That could include soil and weather data, a stream of aerial imagery, as-applied data directly from the machinery, and much more.

Summary

The progression toward information-driven agriculture necessitates an operation-adaptive approach to FMIS which supports farmers’ long-term control of their data. The OpenATK approach allows a farm manager to put
together a data management solution that is tailored to the specific needs of the farm. The APIs and distributed data model used by the OpenATK FMIS allow farmers to focus their time and talents on crop production rather than on managing the vast amounts of data they use throughout a growing season.

Farm management and operational data should be accessible and understandable outside the apps (which collect the data) themselves to better facilitate true data ownership by the farmer. The hope is that 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 future of the OpenATK FMIS should automate data collection tasks by using intelligent algorithms and interfacing externally available data sources to infer context about the situation. This should simplify the work load on the operators and increase the value for the farm management. It is the backend of implementation which will lend the largest value to the data collected.

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