Project Experience Report

Brandon Hillbom and Dillan Zurowski

200426340 and 200431334

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Table of Contents

List of Figures

Introduction

Problem

Farmers are currently left in the dark when it comes to the factors influencing their crop grades, resulting in inaccurate assessments and financial uncertainties. Each grain bin receives a single grade without disclosing the grading factors, leaving farmers unaware of the true quality of their crops. The grade is based on the quality of their grain sample, with tests made by an official evaluator. Contracts for the grain are made between buyers and farmers. These farmers mitigate risks by selecting contracts before, during, and after harvest based on their estimate of the grain's quality. This estimate is often based on past years' contracts, changes in weather or soil analysis, any samples taken for evaluation, and the current market price. However, this estimate is comparable to being blindfolded and throwing a dart at a board. This results in uncertainty in the evaluated grade as it is often either below the contracted grade which results in penalties, or better than the contracted grade which results in missed financial opportunity. These commercial farmers are also unable to know which changes need to be made to ensure improvement of the quality of their crops in the following years, as the evaluators don't disclose the grading factors that bring down the grade the most. With farms spanning thousands of acres and numerous bins, farmers struggle to obtain accurate quality assessments and negotiate fair contracts.

Objectives

Intelligrain, powered by Ground Truth Ag's advanced Computer Vision (CV) technology, disrupts this paradigm by offering real-time insights into grain quality during harvest. By leveraging periodic sampling, Intelligrain provides a detailed breakdown of contributing factors to crop quality, enhancing farmers' ability to make informed decisions and improve crop yields, year after year. Farmers can now visualize the makeup of their fields, filter predictions by grade and specific characteristics, and identify factors affecting crop quality.

Scope

This project's scope was defined as creating an application with as few expenses as possible with the offer of cost covering from Ground Truth Agriculture. Our project did not have any expenses as we used Free Open Source Software (FOSS) or limited versions of technologies such as Mapbox_gl for our map display API which is a flutter-based, community-driven version of Mapbox, and the free version of Google Firebase for our database. This project will be handed off to Ground Truth Agriculture, meaning scalability was an important consideration. This application is designed for mobile use for Android devices with the plan of integrating iOS devices in a future iteration. The decision was made to move field creation and notification settings out of scope as a result of time constraints. The use of a web application was also deemed out of scope due to time constraints and incompatibility with our map API.

Stakeholders

The main stakeholders for this project include the developers, Brandon Hillbom and Dillan Zurowski, the team at Ground Truth Agriculture who provided us with the problem, sample data, and assistance when needed, and the farmers who provided valuable feedback throughout the lifecycle. Other stakeholders include our Capstone coordinator, Tim Maciag and our project mentor, Trevor Douglas. The Northstar customers are commercial farmers who will receive the valuable benefit from using this application. Carryover customers include combine drivers, agronomists, and other team members who would benefit from accessing precise data about their crops.

Outcome

Final Requirements

The scope and objectives continued to change over time as we performed user testing and took part in discussions with Ground Truth Agriculture regarding the direction of the project. Over time, the objective became more clear and our visions were aligned. The final requirements included a mobile application that displayed a progressive map of the grain samples. Each sample should show the underlying factors downgrading the grain and the image of the sample in real-time to the combine drivers. It was also important that all important information, including the map, was available on one page to limit driver interaction with the application while operating the combine. It was also a requirement that the map should be exported to a shape file so that farmers could overlay it with other map data they have regarding soil, land elevation, and more.

Furthermore, our application needed to be able to integrate with their current system to access data from the onboard Orange Pi computer.

The Results

Map View

The main page on our application is the Map View page. This page consists of a satellite map of the plotted points collected from the camera. Each point represents a sample taken by the CV camera. The image from the sample is analyzed to find impure grains. For example, grains could be severely sprouted, bin burnt, contain foreign material, frost, or other damage which brings down the grade of that sample. The full list of available grade factors is currently at 30 across 3 possible grains: Canadian Western Amber Durum, Canadian Western Red Spring Wheat, and Red Lentils. The CV model scans each grain for these factors and returns an overall weighted grade with the factors that are downgrading it. This overall grade can be grade 1, grade 2, grade 3, feed, or sample, where grade 1 is a perfect grain sample and sample is the worst. In this map, the colors correspond to the overall grade of each sample where grade 1 is green, grade 2 is yellow, grade 3 is light red, feed is red, and sample is dark red.

Figure 1.1 Driver's view of the map uploading in real-time

Role-based access was important for this page because, in the field, the combine driver will see a live progression line as the CV camera on their combine takes new samples and generates new data. This will occur roughly every 30 seconds. If the user is signed in as a driver, the map will update to add the new sample to the map. On the other hand, if the user is signed in as an admin, the data will come from all combines via the database, meaning there will not be a live progression.

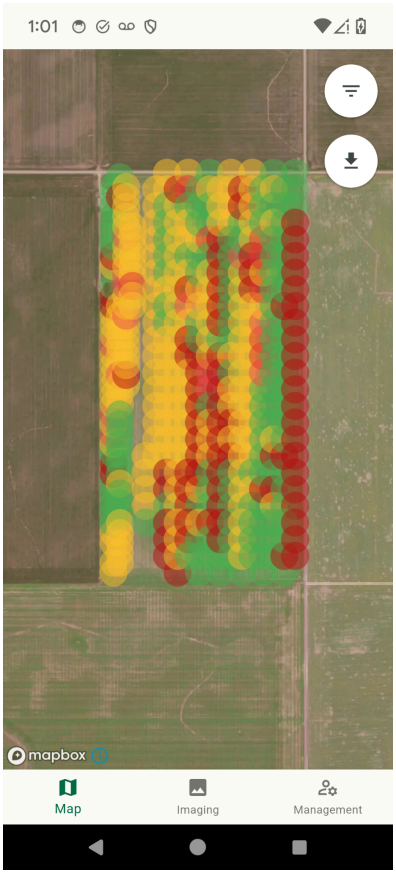

Figure 1.2 Admin's view of the map with a full field filled out

Imaging View

Next, we have the imaging view. This can be accessed in two ways: by clicking the image tab at the bottom navigation bar, or by clicking a dot on the map. Clicking the icon on the navigation bar displays the image of the most recent sample. If you are a driver, it will update in real-time as new data is collected. Here, the ability to pause and play is shown, where the pause button stops the page from updating to the new sample, and play brings back the most recent predictions. This allows the driver to examine a sample more closely if needed. On the other hand, if you click a specific point on the

map, the imaging view will display the information for that sample and the live functionality will be paused. If you are signed in as an admin, clicking the image tab will show the most recent predictions without the ability to see them come in live. However, any time they navigate to the imaging view or map view, the data will fetch any new data from the database. In a future iteration, a database listener could be added to implement the live functionality.

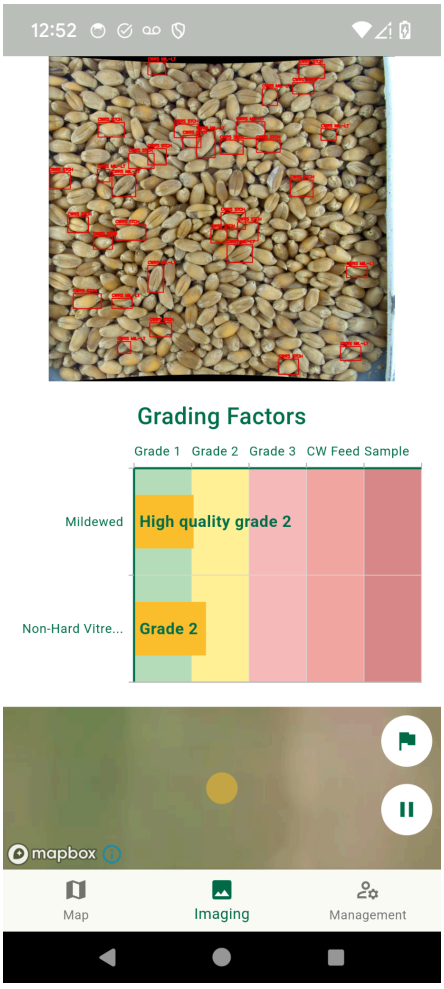

Figure 2.1 Imaging view

This page is very useful to the farmers as it displays everything they need on one page, and from the user testing we performed, the touch-free abilities of the live feature are highly desirable. At the top of the page is the image that the CV camera took along with the bounding boxes around the individual grains of concern with labels describing the type of grain found. In the middle of this page is the grade factors graph which displays the factors that are bringing the grade down the most which corresponds to the bounding boxes. The length of the bar is based on specific thresholds for each factor as a grain with mildew will not be as impactful as an Ergot grain. Below the graph, is a map showing the point being displayed, along with a flag button, and the pause/play for drivers. Flagging a sample is useful in the event a driver sees a sample that should be viewed at a later time. Flagged features can also be filtered via the Map view page.

Team Management

The management page is where we have a list of management-related pages. Currently, the only page available is the Team Members page. Future iterations will contain features such as field management and notification settings. This page also includes a user settings page where you can change your email, job title, password, and name, as well as log out of your account.

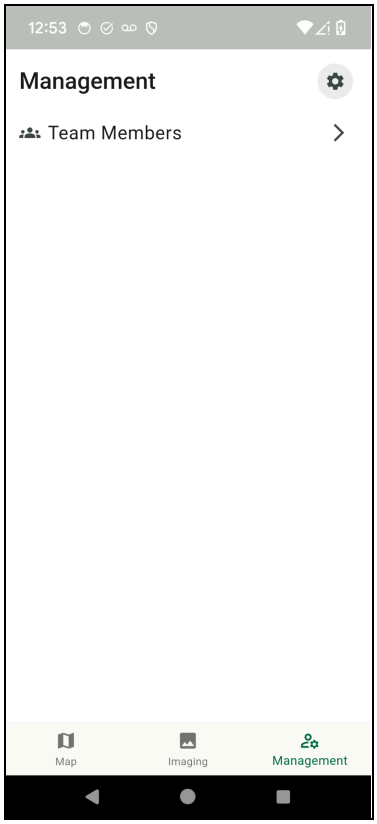

Figure 3.1 - Management Page

Organizations

On the Team Members page, you will see the list of users associated with your farm. If you are an admin, you can invite a new user who can be another admin, a driver, or “other” which could include agronomists and marketers. You can also easily activate users, deactivate users, and resend invite emails if the invitee missed it. Each item in this list shows the user's name, email, and title which is can be set during account creation after accepting their invite email.

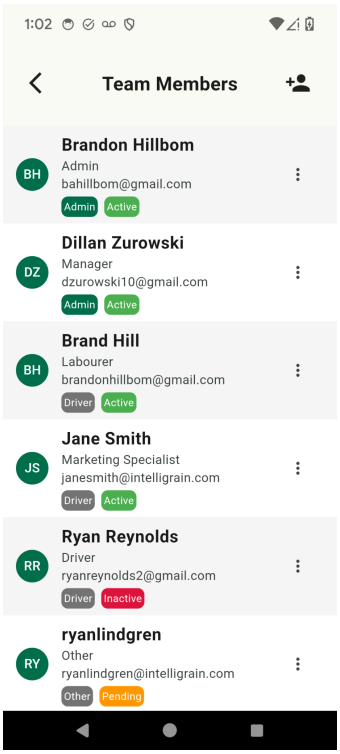

Figure 3.2 - Team Members Page

Role Based Access

Role-based access is important for this application as there are three types of users: admins who are the farmers overseeing the operation, combine drivers who will be collecting the data via the CV camera as they collect grain in a combine, and other users such as agronomists and marketers who will have a read-only access. This will allow them to see all grain data and download the map but they will not be able to generate data or manipulate team member access. Admins will likely be at their farm or another location managing their harvest, this means they will need to access all data from the database including the sample data for the map. Admins are also able to manage their team including adding, deactivating, re-activating, and resending invites to members of their team. Since drivers are in the field actively collecting data and only

care about the data they are collecting, their sample data will come directly from the file being updated by the onboard Orange Pi computer. Once collected and type-checked properly, the new sample is saved to the database using our application where the admins and other users belonging to the farm can view it.

Impact on the Agriculture Industry

Farmers accept contracts for their end-of-harvest yield before, during, and after harvest, but the question is: how do they know what grade to select? During our user tests, we found that the only method of selecting a grade is to pick the same grade as the previous years and make an educated guess based on weather, soil changes, and elevation changes. This leads to inaccurate assessments. Our app allows farmers to make more informed decisions regarding their contracts as they can easily see the quality of each section of their field. For an average combine speed, a sample every minute would produce a prediction every 66 meters or every 33 meters for a 30-second sample rate. Selecting the right contract leads to less opportunity loss and better risk management. They can also use the application to see the real grade of the field and not settle for generalized evaluations that price the grain as less than what they think they deserve. This has the potential to entirely change how grain is evaluated in the future.

With our app, farmers can make informed decisions regarding their process for the following year based on the quality of each area of their field. Historically, this is the first time farmers will be able to determine the quality of each region of their field during

harvest which can help them make informed decisions of what to change in the following year to improve their crops' yield. Additionally, better crop yields mean higher quality produce and more output which will produce more food for a growing population that will always demand more. On an international scale, this would allow Canada to have the metrics to properly back up any claims they might have of having higher-quality grain.

Project Reflection

What Went Well

One thing that went particularly well for us was the transition from a pure flutter-based application to separating concerns between the front-end and back-end using FastAPI calls. This transition was surprisingly smooth and enhanced the performance of our app significantly as the heavy workload of calling and returning Firebase queries is done on the server asynchronously rather than the device itself. This allows us to make larger queries and have better control of the data being passed to our application. This also allowed us to add more features like exporting the map as a shapefile using Geopandas, a Python-based package. Although we felt our first 4 months were poorly used due to student life constraints, we felt we recovered nicely.

Our feature implementation pace was also very good for the second half of the year. Since we had a lighter class load in the second semester, we were able to spend a significant amount of time developing. We are both happy with the rate at which we added features and took care of bugs. During our final meeting with Ground Truth

Agriculture, they expressed how impressed they were with the amount of work we got done between each meeting.

We are also happy with the work breakdown between members. Brandon mostly focused on the front end, including designing and implementing all user interfaces, logic concerning the map and grain predictions, and project management initiatives. Dillan mostly focused on the data flow behind the scenes including configuring data models, creating the FastAPI server, and coding the Firebase queries to connect with front-end workflows. This worked out because we decided to focus on our relative strengths.

Our access to our customers and end users also was a great benefit to the project's success. We actively connected with both farmers and Ground Truth Agriculture stakeholders. With Ground Truth Agriculture, we ensured the alignment of the vision of this application, continuously refined requirements, and discussed updates regarding data models, test data, and feedback regarding user experience. They also provided us with real farmers that represent our Northstar customers. We were able to meet with these farmers multiple times which helped us greatly improve our design, fixing elements that did not make sense or adding features that solved the problems they described.

What We Can Do Better Next Time

We failed to properly account for the massive amount of data being handled and the impact on performance even though we knew it would likely be a factor. We were too focused on rapid iteration and following the path set out for us rather than taking the time to properly plan and design our system. This failure was a result of playing catch up due to the lack of progress from the first semester. Essentially, our approach followed an agile methodology but this emphasized rapid iteration of project features rather than a waterfall method which likely would have influenced us to address this issue. However, a waterfall method likely would have cost us important design decisions that we made as a result of agile.

We also failed to properly plan code tests while we were implementing code. Finding a balance between coding and writing tests was difficult for us as limited time constraints forced us to focus almost entirely on coding until the end of the project lifecycle. Next time, we could properly plan out each function/feature and create test plans for each of them to ensure the functions worked as intended and code coverage was much higher. We also often faced issues with our data models as the sample data we were given by Ground Truth Agriculture changed frequently, so creating better test plans and ensuring quality code would have been beneficial.

As mentioned in various scrums throughout the term, we intended to have the project compatible with both Android and IOS devices. However, we had issues with the iOS environment. We spent a considerable amount of time focusing on this issue rather than progressing our application further which caused us to fall behind in our schedule.

Although we reached out for help from our mentor, we were unable to solve this issue. After consulting with Ground Truth Agriculture, we were told Android would be sufficient so we amended the project requirements as a result.

Your customer is not your user! We were biased towards Ground Truth Agriculture's vision of displaying the samples as a gradient of grade colours on the map. After implementing the path in a couple of different ways, we reached out to farmers for feedback. We should have spoken to farmers before discussing any solutions with Ground Truth Agriculture. We unprofessionally assumed that Ground Truth Agriculture's vision for the solution came from prior knowledge of the farmer's problems. After properly testing with farmers, we redesigned our map a third time. This solution not only satisfied the farmers, but it improved map performance ten-fold. Realistically, it would have made sense to take the time to produce high-fidelity prototypes to receive rapid feedback and iterate accordingly but there was plenty of uncertainty regarding the capability of our map plugin.

Conclusion

This project provided us with the opportunity to create a project and iterate upon it in a true engineering environment. We learned about the importance of project planning and how creating proper designs, testing plans, and setting up initial user tests with low-fidelity and high-fidelity prototypes can lead to a more focused and accurate project development as there are fewer changes over time which is something that we struggled with in this project. However, we did learn how to perform meaningful user tests as well as how to properly receive and adjust to their feedback. We also learned plenty about the full end-to-end project development

lifecycle. This process also showed us that we are able to push further than we thought we could. After semester 1, we felt like we had barely moved forward but we were too stubborn to let that stop us. We had worked hard in school all our life but this was different. Any spare time we had went into this project. We powered through burnout, adapted where necessary, and finished our capstone with the knowledge that we did everything we could. While we still endure a sense of incompleteness due to our ambitions with this project, we believe we achieved our goal of providing a useful tool to commercial farmers. Furthermore, we are grateful for the opportunity to work on a project as meaningful to the world as this one.