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Mr. Melaragno and FABE Capstone Course Advisors:

Please find the final design report for the *Low-cost Drone and Sensor for Agricultural Applications on Small Farms in Tanzania* project attached. With some minor developments, we believe that the package and application we have assembled has the potential to make a true impact in the lives of smallholder farmers in Tanzania. Details about the design process and final outcomes are enclosed in the following pages. As an additional note, be sure to view our informational videos that are posted on YouTube:

https://www.youtube.com/watch?v=dnUTZ1loEh8&list=PLfybhc8W6SgC0u3_4rSwrWaxUS62SJcq.

We would also like to take this opportunity to sincerely thank each of you, as well as Sami Khanal, for your roles in making this project possible. If you have any questions or concerns about the enclosed material, feel free to reach out to any member of our team.

Sincerely,
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Low-cost Drone and Sensor for Agricultural Applications on Small Farms in Tanzania

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1 Executive Summary

The Global Water Institute indicates that agriculture is the top industry in the Tanzanian economy, but states that crop yields remain up to 75% below the standard due to pests, disease, poor input quality, unhealthy soils, changing weather conditions, and bad management practices. The use of drones has tremendous potential to identify these issues and allow for correctional measures to be taken. Drone systems can be implemented relatively easily without additional infrastructure, and while there are some available tools on the market for evaluating aerial imagery, most only focus on one crop or yield-limiting factor and require expensive subscriptions that smallholder farmers cannot afford. The goal of this project was to develop and evaluate a low-cost and low-risk drone package for agricultural consultants that uses analytical approaches for evaluating aerial imagery of crops in Tanzania.

The developed package features hardware and software. The hardware primarily includes the DJI Mavic 2 Pro drone and spare parts, as well as a solar charging backpack. The drone was selected using decision matrices and budget tables, which had a strong focus on balancing cost, portability, flight time, and image quality, among other factors. The software includes a desktop-ready application that utilizes aerial images to immediately identify problem areas in the field and provides the GPS coordinates of the location. The location of each image is represented on top of a Google Map with four different colors to indicate the severity of the issues present in each image. While the application does not currently indicate an exact cause of yield loss, it does allow for a more quantified crop health analysis. This output allows for a directed scouting approach, where farmers can more efficiently determine causes of yield loss in their fields and direct inputs only to the needed areas.

Preliminary results from the use of the desktop application with test images provided by Dr. Sami Khanal indicate that each image takes 0.62 seconds to process. Calculations demonstrate that this can be translated to approximately 1 minute per acre equivalent scouting time. When compared with an approximate on-foot scouting time of 5.2 minutes per acre, this results in a 80.8% time and labor savings in identifying the presence of an issue. This will allow farmers to more quickly identify which problems are occurring in their fields and help them determine which ones are the most important to treat first.

Future recommendations for this project include further development to identify specific crop health issues, validating the application with images collected with the DJI Mavic 2 Pro from fields in Tanzania, and converting the desktop application into a mobile format that will increase ease of use and make the system even more portable.

2 Introduction

The Global Water Institute (GWI), with liaison Jeff Melaragno, works to solve water quality and poverty issues related to agriculture and natural resources in Tanzania and around the world. In order to address the issue of significantly reduced yields across all crops in Tanzania, GWI believes that the use of imagery from drones has been recognized as a plausible solution that can be implemented relatively easily. These systems require little to no additional resources or infrastructure to be installed.

Crop yields can be reduced by many factors, which vary widely depending on the crop, geographic region and growing season. These factors may include insects, weeds, soil pH, drought or flooding, nutrient deficiencies, disease, not using genetically-improved or treatment-improved seed, and a lack of knowledge on implementing good management practices. Due to the wide variations in potential problems that can limit yields, it is difficult to pinpoint a specific cause and make a recommendation for all crops in a single system.

2.1 Project Rationale

The goal of this project was to provide an opportunity for data collection and a crop health assessment that can potentially be applied in all crops and regions in Tanzania. In the current market, many applications that analyze crop health are available, but may only focus on one single crop or yield-limiting factor. They also have significant up-front costs, require the use of additional sensors that are a significant expense, or have a steep yearly subscription fee that the smallholder farmers simply cannot afford. A need was identified for a low-cost, and primarily commercial available system that will quantify crop health efficiently and fill that void. Since most farmers in the area are unlikely to invest in widespread treatment for yield limiting issues, the target outcome was a directed scouting approach, in which a problem area is identified and indicated on top of a Google Map. This service will be provided by agricultural consultants to these smallholder farmers because the consultants will be properly trained to use this technology. The farmers will then need to manually inspect those particular areas of the field in order to determine the cause and take appropriate action, if their finances and available labor allow. This can allow them to reduce the financial investment required in order to treat problem areas and provides evidence of the issues at hand. It is an improvement over the previous technique, where farmers are only able to physically walk their fields and cannot identify features that can be seen from above.

2.2 Project Definition and Scope

Tanzanian agricultural consultants need a low cost and low risk drone and sensor package that demonstrates analytical approaches to evaluate aerial images, identify

locations of issues, and make smart input decisions about agricultural field conditions. The development of a system to complete crop analysis can present many challenges. In initial talks with the project sponsor, cost reduction was pinpointed as the most critical project requirement. A low-risk (commercially available) system was also identified as a crucial element. The scope of this project included choosing a commercial drone and spare parts, development of a desktop app which pinpoints locations of severe crop health issues based on image analysis, and preliminary testing of the application using images from previous growing seasons in Ohio.

3 Background (Literature Review)

The main problem identified in the scope of this project was finding ways to monitor and analyze field conditions for smallholder farmers so they can feed themselves and their families, and potentially have extra crops to sell as a result of decreased yield loss. However, the scope of the project has significantly changed and developed from what it was initially. Initial research was conducted in five areas: agriculture in Tanzania, climate and weather in Tanzania, previous and current drone use in Tanzania, airspace and regulations, and commercially available drones. Additional information on these topics, and their impact on the project appear in the following paragraphs.

3.1 Alternative Methods of Solving Problem

One of the most commonly used methods for monitoring crop health, and essentially the only method used in Tanzania at this time, is on-foot scouting. Some precautionary methods to reduce crop stress and health issues include using herbicides and pesticides, using higher quality seeds, and implementing irrigation. On-foot scouting works if there are enough people and enough time to constantly survey the farm land for problems, however, since smallholder farmers are often family-based and do not have outside help, this poses an additional barrier. Additionally, smallholder farmers do not have a lot of money readily available to invest. They are unable to purchase disease prevention products and high quality seeds. When they can afford those products, packaging is often in a language they do not understand and as a result they are unable to use it.

While there are some solutions for the use of drones available, many are focused on only one aspect of crop stress or even only on a single crop. Other tools are designed to predict crop yields, not to address the yield limiting factors (Lopez-Lozano, 2018). The new drone package in development will provide an easy-to-use, real-time solution to find areas in smallholder farmer fields that need attention across a variety of crops and geographic regions. The farmers would initially receive the services for free from their agricultural consultant (Global Forum, 2018). Ideally, crops would be surveyed using the

drone once a week, or once every two weeks. If the program is successful, it could move to a consultant-based business platform.

3.2 Competitive Analysis

When looking at what other applications are on the market for field analysis, there were four other applications that do similar functions: ID Weeds, FarmLogs, AgMobile, and Canopeo (Walter 2016). ID Weeds can detect weeds in the field and tell the user what kind of weed it is. FarmLogs quickly maps field boundaries and has information on that field including rainfall data, soil maps, yield maps, and growth stage estimates. AgMobile offers market information, news and weather (Walter, 2016). Finally, Canopeo is an app that has a rapid and accurate green canopy cover measurement tool. This app helps quantify the percentage of canopy cover, monitor crop progress, and make informed management decisions. However, Canopeo is intended to be used from the ground, so has limited applications in terms of monitoring stresses across the whole field. For example, the camera on a phone is held up by the user and then the output shows the user in white pixels what is live green vegetation and black pixels shows all other background (Patrignani).

While all these applications incorporate aspects of what the custom app is going to do, none of them directly compare. All of the applications are made for places in the United States. Developing a customized application will allow for specialization to the Singida region in Tanzania. The app that compares to the goal of the project best is the Canopeo application. It is similar in that it uses images and provides an output of showing healthy crops. However, the custom app is going to look at overall field conditions and analyze the land using a drone. The custom application will be able to process images from a drone, georeference those images to land in Tanzania, and produce an output that can be easily understood by the agricultural consultants. The output produced will specifically provide smallholder farmers with what areas in the field needs attention. It will be shown visually and provide coordinates for that location.

3.3 Target Markets or Potential Financial Impact

For this project, the focus is the Singida region of Tanzania. The target market includes both the agriculture consultants and the smallholder farmers in that region. The drone package being developed will be given to a consultant and they will provide guidance and data to the smallholder farmers (GWI, 2018). Since smallholder farmers farm for themselves and their immediate families, any data given to them in order to produce healthier and more crops is imperative.

When looking at the potential financial impact of the drone package for GWI, the hope is to see return on investment in one to three years. The drone package will be purchased

by the agricultural consultants in Tanzania. Those consultants will then charge smallholder farmers to use the package on their land. However, in the beginning, the drone package will be given to agricultural consultants and they will work with farmers at no cost to show the benefits of the application before moving to a fee-based business model. In the end, all parties are expected to see improvements: the farmers will be able to produce a larger volume and higher quality of crops with the services of the consultants and the consultants will see a return on investment.

3.4 Patent Search

Three patents were researched that could prove helpful with designing image analysis software:

1. US Patent 7893875B1 for device for and method of geolocation can be used for the implementation and installation of a GPS unit with the drone or mobile device.
2. US Patent 2004/00329731 A1 for method for using remote imaging to predict quality parameters for agriculture commodities can be useful for determining color thresholds that can be used for predicting crop health.
3. US Patent 2013/0051651 A1 for quantitative image analysis for wound healing assay could provide imagery for results that farmers would see if farmers planted in different areas or used different crops.

3.5 Commercially Available Drones

A large component of the project is to select a drone that will be bundled with other items. As seen in Table 1, a search was done on commercially available drones used in agriculture health analysis and research to create a list of drones to look into further. From this list, a few constraints were applied to narrow down the selection. Cost, lateral range, altitude, size, portability, and total moving parts were considered for selecting the drone that will be included in the package. The DJI Mavic Pro was selected for the package due to its transportability (1.64lbs, 3.26772"x3.26772"x7.79528"), flight distance (8 mi), flight time (27 mins), and ease of use (DJI Official, 2018).

Table 1. Decision matrix used to determine which drone to purchase for use in package

	Weight	Yuneec Typhoon	*DJI Mavic Air	DJI Phantom	DJI Mavic Pro
Cost	0.2	3	3	4	3
Range	0.25	2	4	5	5
Battery Life	0.25	3	3	5	4
Mobility	0.15	2	5	3	4
Camera Resolution	0.05	3	3	5	3
Altitude	0.1	3	3	3	3
Special Features		0.1	0.1	0	0.1
SCORE		2.7	3.65	4.3	4

**Ranked 1-5, 5 being best

Estimated Cost	\$800	\$800	\$700-1,000	\$800-1,000
Additional Notes to Consider in Selection (Special Features)	*Extra battery for \$127 *Output voltage 11.1V *Weighs 15lb *Remote comes with screen on it; live feed *Backpack case (separate)	*HR photos *Transmission distance - 2km *Foldable remote controller; holds smartphone - shows live feed *430 grams *Foldable	*Older generations, price can be lower *1370 grams	*Older generations, price can be lower *730 grams *Foldable

3.6 External Systems

Components that would not directly affect the drone package but had to be considered are that the normal rain seasons are becoming less consistent due to changes in the environment. The heavy winter and light spring rains are shortening and occurring earlier and more sporadically during the year (Seasonsyear.com, 2018). This causes less time for farmers to grow their crops due to the rains flooding the land more often. This is an aspect that has a large impact on the importance of scheduling an agricultural officer to survey a specific area during a normally calm time of year. This change also emphasizes the seriousness of the use of this technology for agricultural officers to survey and analyze the farmland. This analysis will lead to better planning for planting

crops in certain areas over other areas due to crop vitality and yield, especially when water sources are becoming less predictable.

3.7 Constraints and Standards

The three biggest constraints the project was given were low cost, return on investment (ROI), and low risk for the consultants receiving the drone package. The entire budget is \$2,000-\$3,000, the consultants must see a ROI in 1-3 years, and the drone package must be reliable enough that consultants do not have to keep receiving maintenance more than once a year (with proper operation). This package will provide some economic support and growth for the agricultural industry by incorporating project constraints that make the system efficient.

Other constraints that are important to consider are using solar power, mobility, weather compatibility, and ease of operation. Since there is not electric power readily available, the drone will need to be charged by a solar charging system. Transportation is also limited within the Singida region, so another factor is that the system must be easy to transport via motorbike, bicycle and foot. There must also be a detailed guidebook for the package that is written in both English and Swahili for the educated consultants to easily decipher. The team must also consider incorporating weather proof materials, since Tanzania has a varying climate. The sponsor indicated that legal standards and regulations would not be a concern for the scope of this project.

3.8 Social and Economic Issues

In Singida, Tanzania, the primary economic activity lies within agriculture. Up to 80% of the workforce is in agriculture, while 75% of the population relies on the agricultural industry for income (Tanzania-Agriculture; Misaki). Since most farmers rely on subsistence farming and the population relies mostly on what they grow, if the growing season is not ideal it can create serious economic burdens and malnutrition.

Tanzania is greatly affected by climate change. The drastic changes in seasons affect the social and economic standards of Tanzania. The rainy seasons and dry seasons make it hard for farmers to have successful growing seasons, which in turn cause loss of property and/or profits from extra crops.

4 Detailed Design Description

4.1 Proposed Designs

Three concepts were generated through the brainstorming process. All three concepts were assumed to utilize the same drone, which was determined by using a decision matrix, with the concept differences stemming from the output method.

4.1.1 Drone with Custom Application

This concept features a drone with the output method being a custom application developed by the GWI Drone team. The app would be created using Python OpenCV and initially developed for a computer, then transitioned into an Android application. The app will be freely available to consultants and would be developed for the specific crops and use in the Singida region of Tanzania. The process that would be developed is called color thresholding. Color thresholding will show the areas of crop health or stress issues as different colors. Green areas indicate that the crop is healthy (the plants themselves are green) and there is more cover. Red areas will indicate poor crop health and areas of concern. This system will allow the consultants to receive information quickly on-site. An example application, as originally conceived, can be seen in Figure 1 at the far left.

4.1.2 Drone with Pre-existing Application

This concept is the reference concept and features a drone package with the output method being a pre-existing software or application already in use. The software or application would either need to be downloaded or a license would need to be purchased. Depending on which one is chosen, the cost would need to be considered for the package. A pre-existing app would have predetermined features would allow the drone images to be analyzed, but they are not specifically developed for the Singida region in Tanzania. This would mean that adjustments would need to be developed to work in the region. This concept would allow the consultant to have information available on site. It would also be supported by the developers of the software and has the potential for many more users to compare information. An example application can be seen in Figure 1 as the center image.

4.1.3 Drone with No Additional Processing

This concept features a drone package with the output methods being the image taken directly by the drone and being analyzed by the consultant on site. It would use the software and resolution of the image provided by the drone and would require the consultant to be able to analyze the image without any additional software. The consultant would be provided a manual to help them interpret the images that would give them example of what they should be looking for. This concept would allow the consultant to have the information on site, but also would require them to analyze the images further and relay that information back to their client. This could be an inefficient use of time and money. An example application can be seen in Figure 1 as the far right image.

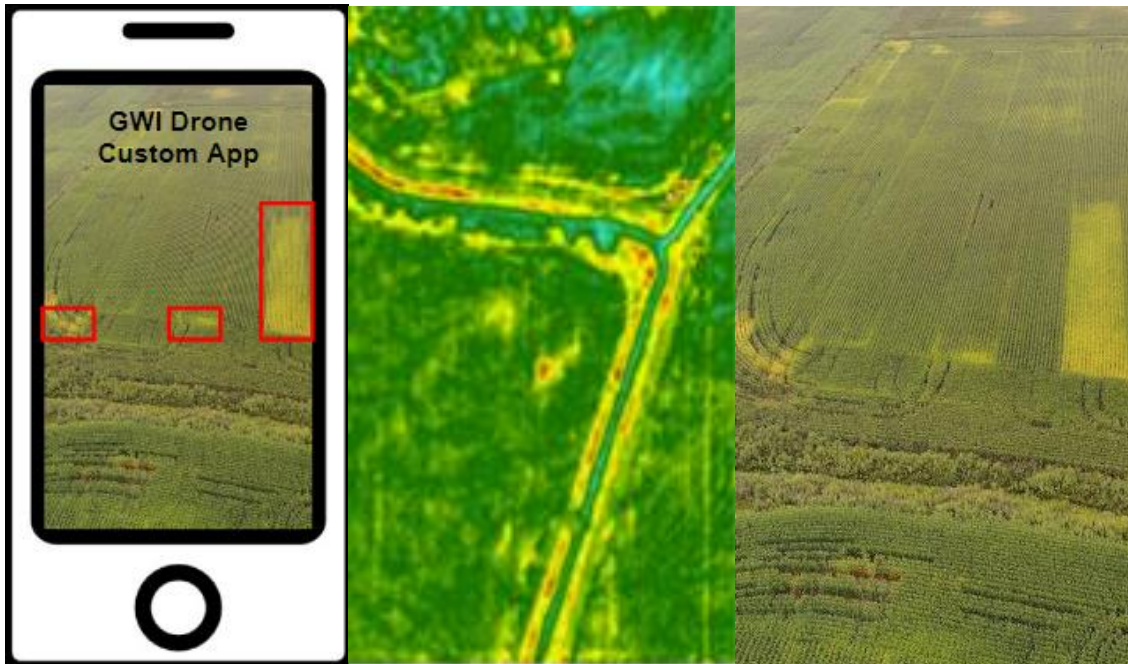


Figure 1. Visual representations of the output of presented concepts. Left to right: 1) GWI Drone Custom App, 2) Existing App/Software (Thermal Imagery), and 3) No App - Visual Analysis Only

4.2 Selected Design and Rationale

The concept selected was the drone with a custom application. After using a design matrix and weighting the different criteria determined to be most important, the custom app had the highest overall score, even though it had the worst score in time of development. It was chosen for multiple reasons. The first was that it would be developed for the purpose of use by consultants in the Singida region in Tanzania. This allows it to have only features that were determined to be most important in that particular area for analyzing fields. The second reason was that it adds no additional cost to the drone package because no license or subscription must be purchased. It also would also be developed using OpenCV, meaning that it is free and widely available. The last reason is that control of the application would be by the team. This means that adjustments can be made as soon as a problem occurs and that the inputs and outputs would be modified as needed. These reasons, and others which have proven to be more anecdotal, mean that the custom app allowed for the drone package to stay relatively low cost and would allow it to be customized for the consultants specifically.

4.3 Detailed Description of Design Components, Materials, and Dimensions

The components of the chosen concept are the drone, developed application, device with the application installed, extra parts for the drone, manual, instructional videos, and a solar charging backpack. A full list of the detailed components is listed in the Appendix B. The drone chosen was the DJI Mavic Pro. It was chosen because of the small form factor of only 1.64 lbs, cost, and maximum flight time of 27 minutes (DJI). The application was developed using Python and OpenCV. The short-version manuals were created using the factory shipped manuals by DJI. These manuals list the components in the package, safety informations, and instructions on how to fly and charge the drone as well as how to use the application to correct analyze the images taken by the drone. The full manuals can be found in the Appendix C. Informational videos have also been shared on YouTube at the following link:

https://www.youtube.com/watch?v=dnUTZ1loEh8&list=PLfybhc8W6SgC0u3_4rSwrWaxUS62SJcq.

The solar backpack is the Voltaic Systems Array Rapid Solar Backpack Charger. Fully charged the battery back included in the backpack is 24,000 mAH.



Figure 2. Comparison of size of the DJI Phantom (left) and the DJI Mavic Pro (right).

5 Design Evaluation

5.1 Methods

The method used to quantitatively define multiple aerial images captured using a drone were discussed and evaluated by the team, with input from the technical advisor (Mordvintsev, A., & Rahman, A., 2013).

By using a series of decision matrices, a choice was made to create a program that would utilize an open source programming language that would not require a user license or yearly subscription. Object-oriented programming languages considered were Python, Java, and C# (Oracle, 2017). A brief definition of object-oriented programming is the ability to call a function or class in different scenarios to create a new variable in the program. The language that the team decided to use is Python, for the vast number of libraries available to use from the Python community, as well as it being a relatively light processing language, and ease of use.

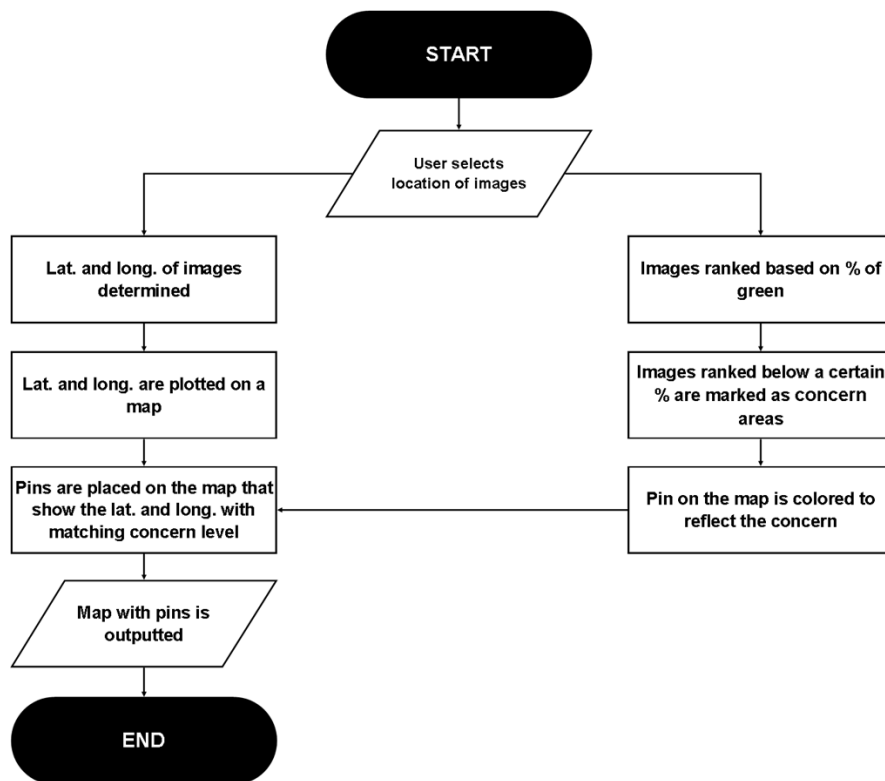


Figure 3. Outline of proposed application workflow

5.2 Data Collected

After deciding on what language to program in, the methods of data collection were decided. The first step was to collect physical data in the form of an image database

that could be used as way to test the program as it developed. This database was provided by the technical advisor, Sami Khanal, and contained images of multiple fields located near Wooster, Ohio.

Once the physical data had been collected, the program was then able to import the following information from each image.

- Latitude and longitude
- Pixel color count

The drone selected has a GPS monitoring system embedded inside the shell of the drone. As each image is taken the latitude and longitude will also be recorded in the EXIF data of the image, where the file formats JPEG and TIFF are the most commonly used.

Every image taken contains a certain amount of pixels and depending on the image quality, the number of pixels will change as well. In this project, a simple RGB sensor was utilized where the colors red, green, and blue are combined to create a different color recorded by the sensor. The concentration of the certain bandwidth of color, that the user defined, was also collected from every image.

5.3 Methods Used for Data Analysis

The methods used to analyze the data collected were straight forward in theory, but required more out of the box thinking when actually applied. Each image has the latitude and longitude from the EXIF data written to each image. Once the image's location is recorded, each image is analyzed by counting the total pixels in the image. Every pixel in the image will have a certain ratio of the red, green, and blue color bands. To quantify the pixels in the image, a lower and upper bound of the color bands was determined and then counted against the total amount of pixels in the image where it is recorded with the latitude and longitude of the image.

To determine an approximation of time savings this program produces, a timer was set to record how many seconds it took to complete the image analysis. The results for how long it would take the program to complete the data analysis over a variety of folder sizes are given in Table 2.

Table 2. Time rate differences for varying folder sizes

Scouting Type	Number of Images	Time (seconds)	Rate
	19	11.39	1.66812993
	19	11.07	1.71635049
	19	10.77	1.76415970
	435	272	1.59926470
	435	403	1.07940446
	435	264	1.64772727
	435	365	1.19178082
	743	13356.67	0.05562763
	743	12254.8	0.06062930
	743	14278.9	0.052034

6 Results

The developed desktop application will save farmers time and provide data for decision making that has the potential to increase their production of healthy crops. The application allows the user to select and define the image directory to be analyzed. The program analyzes all the images that are in the folder selected. Then, all of the image pixels are compared to a predefined color (i.e. green). A color ratio is then used to define the color of a marker placed on a Google Map at each location as shown in Table 3. Figure 5. Red represents the areas in the field that need the most attention and are the furthest from the predefined green. In order to place the pins on the map, the program finds the latitude and longitude for the photos and presents it as shown in Figure 6. Completing the analysis for 435 images took 4.5 minutes and 1.61 images/second are processed. The code that was developed is shown in Figure 4.

When looking at the time savings that the app would provide, it was found that there would be an 80.8% labor and time savings. It would take 5.2 minutes to scout one acre on foot. Using the developed application it would only take 1 minute per acre to scout the field. That is significantly faster and would allow the farmers to have more time to work on mitigating the damaged or diseased crops instead of spending that time scouting on foot.

```

length=len(onlyfiles)
latitude = []
longitude = []
color_ratio= []
# image path and valid extensions
imageDir = tempdir # specify your path here
image_path_list = []
valid_image_extensions = [".jpg", ".jpeg", ".png", ".tif", ".tiff"] # specify your valid extensions here
valid_image_extensions = [item.lower() for item in valid_image_extensions]

# create a list all files in directory and
# append files with a valid extension to image_path_list
for file in os.listdir(imageDir):
    extension = os.path.splitext(file)[1]
    if extension.lower() not in valid_image_extensions:
        continue
    image_path_list.append(os.path.join(imageDir, file))

start = time.time()

# loop through image_path_list to open each image, analyze it, and create an array for lat, long, and color ratio
for imagePath in image_path_list:
    lat, long = get_exif_location(get_exif_data(imagePath))
    lat = round(lat, 4)
    long = round(long, 4)

```

Figure 4. Example of code used in program

Table 3. Sample output of latitude, longitude and color ratio from code

<u>Latitude</u>	<u>Longitude</u>	<u>Color Ratio</u>
39.9659	-83.4402	4.981
39.966	-83.4406	2.323
39.9661	-83.4409	2.751
39.9662	-83.4412	2.963
39.9663	-83.4415	2.737
39.9664	-83.4417	2.375
39.9664	-83.442	3.480
39.9665	-83.4423	3.810
39.9666	-83.4426	2.529
39.9666	-83.4431	0.531
39.9665	-83.4428	0.902
39.9664	-83.4425	2.446
39.9664	-83.4423	2.623
39.9662	-83.4417	2.599
39.9661	-83.4414	2.901
39.966	-83.4412	2.795

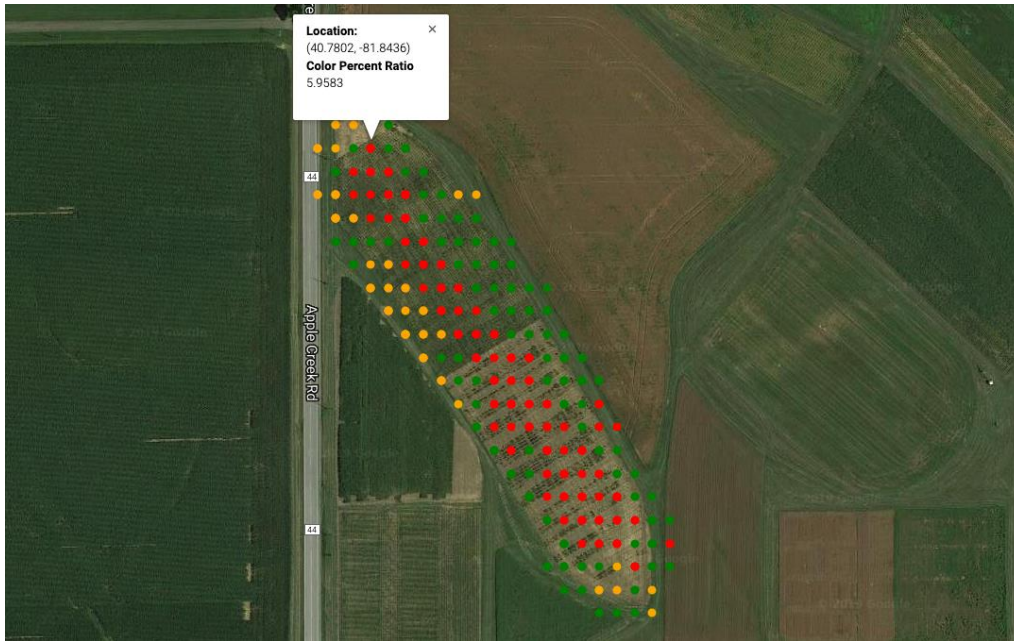


Figure 5. Sample output of map with interactive pins from code

To test the hardware portion of the package, a test flight and battery trials were completed. The drone was flown for testing in Marysville, Ohio and worked as expected. Average results from three trials of charging times for the drone battery and the remote controller are presented in Table 4. As shown below, utilizing the solar charging battery pack did not have a significant effect on the charging time of the devices.

Table 4. Comparison of battery charging times from standard wall outlet and Voltaic solar charging backpack battery pack

<u>Average Battery Charging Time Comparison</u>			
Device	Standard Wall Outlet (minutes)	Solar Charging Pack (minutes)	Difference (%)
Mavic Pro Battery	80	84	4.9
Remote Control	102	109	6.6

A statistical analysis was done comparing the time it would take and distance that would be able to be covered using on foot scouting versus the drone and application. Table 5 shows the mean time in seconds that it would take to scout a certain number of acres. As you can see below the time it takes for the drone and application is significantly faster than on foot scouting. Additionally, the drone time does not really increase when more acres are being scouted. Then, looking at Table 6, it shows the time it takes for

the application to run a certain number of images in seconds. While the total time does increase when the number of photos are increased, the time it takes for an individual photo to be analyzed gets lower. Figure 6 provides a visual representation.

Table 5. Mean, standard deviation and variance for scouting versus application

Scouting Type	Area (acres)	Mean	Standard Deviation	Variance
Standard Scouting	4.4	1571	60.5	3667
	5.5	1963.6	75.3	5684.3
	10	3570	137.4	18900
App Scouting	4.4	396.6	5.7	33.3
	5.5	400	10	100
	10	401.6	10.4	108.3

Table 6. Mean, standard deviation and variance for each test

Scouting Type	Number of Images	Mean	Standard Deviation	Variance
App Run Time	19	1.716213379	0.04801502901	0.00230544301
	435	1.379544317	0.3150645704	0.09926568349
	743	0.0560972542	0.004316444466	0.0000186316928

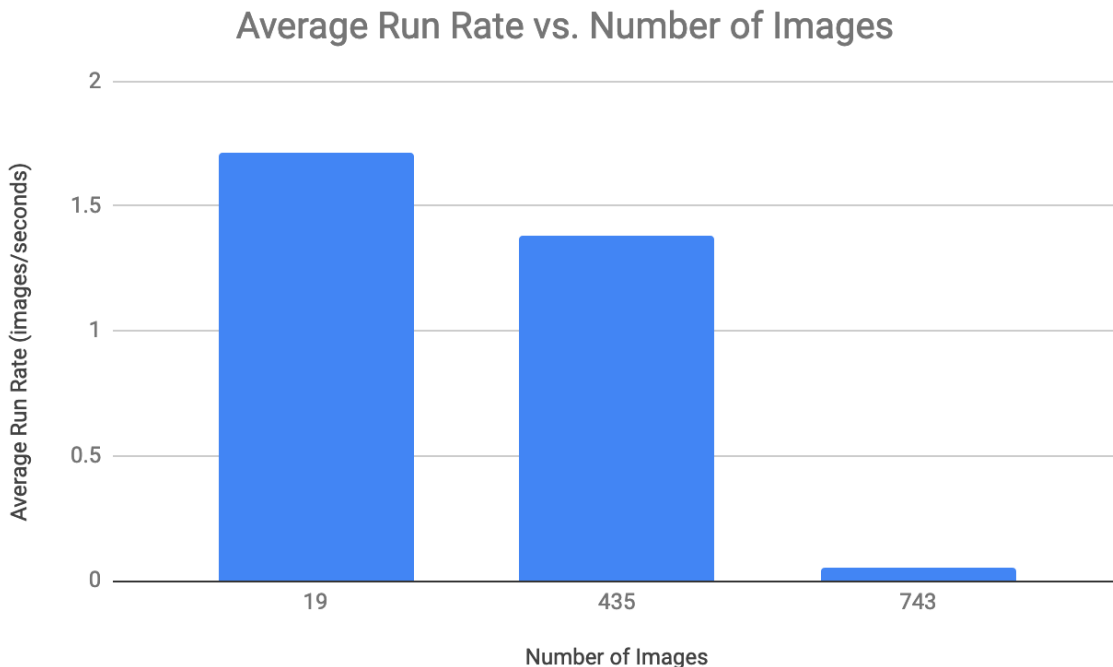


Figure 6: Comparison of how long the program takes to analyze a folder given different element lengths

7 Cost Analysis

The total cost of the drone package is \$1,243.36. This price included the purchase of the DJI Mavic Pro Drone with extra parts, a solar charging backpack and operation manual. A full list of items with pricing for the drone package can be found in Appendix B. The commercial items are very accessible. All of these components were purchased off of Amazon, so there will not be any issues replacing parts if complications were to occur.

This package will be given to consultants who can, hopefully, implement this system into a profitable business. Initially, the process will be free of charge to verify that this method will help smallholder farmers have a higher crop yield and/or gain a profit from the intervention. After this is confirmed, the consultants will be able to charge an affordable fee for the image analysis services and begin to retain a profit. GWI will work with the consultants to determine an affordable and profitable fee to charge for the drone package services.

8 Further Design Considerations

8.1 Environmental and Sustainability

Consultants in Singida, Tanzania will not have unlimited access to electrical power to charge the drone, so a solar power charging backpack has been provided. This component will also double as being a cleaner source of energy. The battery powered drone will also not produce any harmful emissions in the environment it is being used in. This is a potentially sustainable alternative to helping farmers identify health issues within their crop fields.

8.2 Manufacturability

The drone package is comprised mainly of commercial components as well as a customized manual and computer application. Since the components are widely available, the manufacturing process of this project would be very simple: buy the listed components outlined in Appendix B. The only component that would have to be continually developed is the computer application. The eventual goal is to have it running as a mobile application and have added deliverables to the image analysis, like water availability and soil quality. This will be further explained in the conclusions and recommendations section of the paper.

8.3 Ethical

Safety is a crucial concern with this product. If this equipment is not handled and stored properly, it could severely injure one or more people. In order to resolve this issue, the operating manual as well as a customized written manual that highlights the most

important concerns and instructions for the use of the drone and application has been provided. This technology will only be provided to trained consultants instead of smallholder farmers that may not be familiar with this type of technology.

Another potential ethical issue for the project is a violation of privacy from flying the drone and taking videos or photos on private property, especially if people appear in the images. Airspace boundaries and ownership are often undefined and unclear, which can result in ethical issues and even disputes. The best way to avoid any potential problems is to get permission from surrounding property owners, ensure that the drone is not flown above people, and to be sure that all applicable laws are followed.

8.4 Social and Economic

Singida, Tanzania is greatly affected by climate change, meaning the climate can vary drastically from season to season. These drastic changes in seasons affect the social and economic standards of Tanzania, because so many depend on agriculture for survival. And since most farmers rely on subsistence farming and the population relies mostly on what they grow, if the growing season is not ideal it can create serious economic burdens and in turn cause malnutrition.

The customized drone application was tested on images taken from crop fields in Wooster, Ohio. Unfortunately, native images from Tanzania were not accessible so the application was not tested on images from the region. This will have an effect on the images analysis because the climate and crop coloring in Tanzania varies from that found in Ohio. Fortunately, the color thresholding in the application can be adjusted to match the coloring found in native crops that the consultants will be analyzing. The next phase of testing should be done on images either received from Tanzania or images taken by the DJI Mavic Pro drone in Tanzania.

9 Conclusions and Recommendations

The primary goal of the drone package is to more efficiently determine causes of crop yield loss, allowing for directed scouting and the use of inputs that can increase farmer's production. Using the drone to take aerial images, processing those images, and directing farmers to the location and problem areas in their fields will lead to time and labor savings. The developed application allows the user to select a folder of images from the drone, provides a location for each image, and determines where the problem areas are. As an additional part of the package, a manual and instructional videos are provided to the user that explain in detail how to set up the drone, fly and take images with the drone, and process those images using the customized application. By using the complete drone package farmers will see 80.8% time savings, as well as an increase in crop production.

Moving forward it is recommended that the application should continue to be

developed to add functionalities that will allow for identifying specific crop stresses, rather than only a stressed area. The application should also be validated with images from the Singida region of Tanzania. Additionally, the desktop application should be converted into a mobile application for smartphones to increase ease of use.

10 References

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11 Appendix

A - Qualifications of Personnel

JENNA K. LEE

(937)243-7835

lee.7210@osu.edu

Permanent Address:

17475 Waldo Road
Marysville, Ohio 43040

Current Address:

1150 Kinnear Road, Apt. 2227D
Columbus, Ohio 43212

Education:

The Ohio State University - Columbus, Ohio Expected Graduation - December 2019

- ◆ Major - Food, Agricultural, and Biological Engineering (Specialization in Agricultural Engineering)
- ◆ Minor - Agribusiness
- ◆ 3.117 GPA
- ◆ Relevant Courses - Fundamentals of Engineering, Programming Matlab, Fluid Mechanics, Thermodynamics, Engineering Economics, Agricultural Structures, Dynamics, Mechanics of Materials, Heat and Mass Transfer, Energy in Agriculture, System Dynamics

Experience:

Ohio State Department of Food, Agricultural and Biological Engineering - Columbus, OH January 2017-Present

- ◆ Precision Ag Program Student Assistant
- ◆ Assist with research on topics including digital tools and apps in agriculture and best management practices in the application of nitrogen and phosphorous
- ◆ Four research presentations at National and International Conferences in 2018
- ◆ Develop programming for growers in order to share new information, including the eFields On-Farm Research Report
- ◆ 15-20 hours/week (during school year), Full-time (May-August 2018)

Lee Farms, Farm Management Trainee - Marysville, OH January 2012-Present

- ◆ Assist with daily operations of 2700+ acre family grain farm, including critical planting and harvest seasons
- ◆ Management of incoming yield data and calibration of grain dryer during harvest; maintaining genetic purity and quality of soybean seed
- ◆ Operation, loading, and cleaning of planter during planting; and other tasks as assigned throughout year

CFAES Prospective Student Services, Group Visit Coordinator - Columbus, OH August 2016-January 2017

- ◆ Planned and developed group visits to the Ohio State College of Food, Agricultural, and Environmental Sciences
- ◆ Organize Blue and Gold to Scarlet and Gray program with attendance of more than 1,500 FFA students the State FFA Convention
- ◆ 10-15 hours/week

Leadership, Community Service and Extracurricular Involvement:

- ◆ **American Society of Agricultural and Biological Engineers, Ohio State Chapter** August 2015-Present
 - President, January 2017-Present
 - Treasurer, January 2016-December 2016
 - Representative to CFAES Student Council, September 2015-December 2015
- ◆ **College of Food, Agricultural, and Environmental Sciences Ambassador** March 2016-Present
 - Ambassador Leadership Summit Attendee 2017
 - Co-Chair Spring 2018
- ◆ **Ohio State Society of Women Engineers** August 2015-Present
- ◆ **Ohio State Agribusiness Club** September 2016-Present
- ◆ **Ohio State Welcome Leader** August 2015, August 2016
- ◆ **CFAES Experience Ohio State for A Day Student Host** February 2016-Present
- ◆ **Education Abroad Experiences**
 - Castles and Cathedrals of England and Wales May 2017
 - Costa Rica: Sustainable Service Learning March 2018
- ◆ **Marysville High School FFA Chapter** August 2010-October 2016
 - American FFA Degree Recipient 2016, State FFA Degree Recipient 2014

Noah Veccia

veccia.1@osu.edu | 1276 Worthington Heights Blvd, Columbus, OH 43235 | 216-409-0938

Education

The Ohio State University | Columbus, Ohio

Bachelor of Science in Agricultural Engineering - Power and Machinery

Expected Graduation: May 2019

Skills & Qualification

- Software: Inventor, SolidWorks, MATLAB, Simulink, Java, ArcGIS, Microsoft Word, Excel, and PowerPoint
- Communication: Team Collaboration, Leadership, Technical Documentation, and Project Management
- Certification: Certified SOLIDWORKS Associate – Academic | Expected: May 2019

Work Experience

Ohio Department of Transportation | Columbus, Ohio

Hydraulics Engineering Intern | July 2018 – Current

- Designed templates for use on site visits by other engineers
- Worked with different departments to effectively complete tasks
- Reviewed project proposals for selection to continue various research projects
- Researched existing design for implementation in future designs of Stormwater BMPs
- Utilized Microsoft Excel and ArcGIS to create a document of septic tanks in Ohio

Fawcett Center | Columbus, Ohio

Student Banquet Manager | September 2016-Current

- Led teams of similar age students to achieve tasks in an efficient manner
- Trained new employees
- Communicated with staff and clients to manage events to client specifications
- Key holder responsibilities

Academic Engineering Projects

Global Water Institute Drone Capstone | August 2018 – April 2019

- Designed an image processing program using drone images to analyze crop fields in Tanzania
- Led the program design and drone selection process
- Collaborated with students from diverse engineering specializations
- Created various documents that used proper technical documentation
- Project presentation to peers, industry experts, and educators

Honda R&D INNOVATE-O-thon | April 2018 – April 2018

- Collaborated with students from diverse educational backgrounds
- Brainstormed various solutions to the problem
- Pitched a design concept to industry experts
- Developed working prototypes based on the concept
- Presented the finished prototypes to other students and professionals

Honors & Achievements

- Marion Campus Scholars | Autumn 2014 - Spring 2015
- 2nd Place in the Honda R&D INNOVATE-O-Thon

Activities

- E-Sports Initiative | September 2015 – Current
- Homegrown Engineers | September 2017 – Current
 - Presented to high school students about various engineering fields and college experiences
- Assistant with Worthington Kilbourne Hockey | December 2018 - Current

Abby Warburton

175 East Norwich Ave. Apt C Columbus, OH 43201
Phone: (330) 309-6035 Email: warburton.18@osu.edu

OBJECTIVE: Starting role as an Associate Consultant at Veeva Systems in August 2019.

ACADEMICS:

- The Ohio State University Graduation: May 2019
Columbus, OH
 - Major: Biological Engineering; Minor: Biomedical Engineering
 - GPA: 3.03
- TE Connectivity Scholarship and Internship Offer Oct 2017
 - Sponsored by TE to attend 2017 SWE Societal Conference and received interviews from TE CEO, Terrence Curtin, and TE Board of Directors Chairman, Tom Lynch.

SKILLS SUMMARY:

- High level of chemistry, biology, and physics lab techniques
- Leadership, responsibility, time management, and organization
- Advanced in Excel, MATLAB programming, AutoCAD, Stella Software and SolidWorks Design

ENGINEERING EXPERIENCE:

- Failure Analysis Intern at TE Connectivity May-Aug 2018
Winston-Salem, NC
TE Automotive
 - Maintained three projects that required mining 15 years of data to develop and expand databases for the failure analysis tracking system and polymers lab.
 - Applied statistical analysis to databases to recognize failure and material trends.
 - Advanced knowledge in operating rheometer and melt flow indexer.
- Society of Women Engineers (SWE) Jan 2017-Present
OSU
 - Section Treasurer, E-board, societal member, 2018 Spring Networking Night Director, scholarship winner, and conference attendee
 - Maintain largest engineering student organization's \$100,000+ budget through extensive and organized excel spreadsheets and help 14 officers manage their individual budgets.
 - Determined important organizational goals, purposes, and incentives for OSU SWE.
 - Actively participated in community outreach, professional development, and organization's social and recruitment events.
 - Mentor for middle and high school girls interested in STEM.
- Project Manager of Drone Capstone Design Project Aug 2018-Present
OSU
 - Lead and manage progress of team designing a reliable, low cost drone mobile application to combat agricultural inefficiencies for Tanzanian farmers.
- Assistant in biomolecular laboratory Jan-May 2017
OSU
 - Learned biomolecular laboratory techniques where focus was on enzyme applications for pancreatic cancer cells.

LEADERSHIP EXPERIENCE:

- Engineering Expo Coordinator Feb 2018-March 2019
OSU
 - Organized and developed a strategy to create the most efficient and cost effective expo for students and employers.
 - Managed expo chairs advising student volunteers and employer escorts.
- Green Engineering Scholars (GES) Aug 2014-May 2016
OSU
 - Participated in intramural basketball teams, volunteering, and environmentally conscious academic courses and events.

Kathleen R. Whalen

Whalen.161@buckeyemail.osu.edu | 615-686-4852 | 33 E. 13th Ave, Columbus, OH 43201

EDUCATION

The Ohio State University, Columbus, OH
B.S. Agricultural Engineering | Business minor

Expected Graduation: May 2019
Dean's List (Autumn 2016, Spring 2017)

LEADERSHIP POSITIONS

- President of Society of Women Engineers (March 2018 – present)
 - o Oversee 18 officers, providing guidance to complete tasks in a timely manner, while helping them to achieve their personal development goals
 - o Serve as liaison between region/societal-level leaders and collegiate section to build the program by partnering with other professional and collegiate sections
- Engineering Expo Coordinator (2018)
 - o Plan for several months prior to event
 - o Interview and select committee members then oversee those committees
- Vice President of Society of Women Engineers (March 2017 – March 2018)
 - o Exec Board position; oversee other officers
 - o Organize monthly meetings and select SWE scholarship recipients
- Student Registration Committee Chair (Engineering Expo; 2017)
 - o Manage process for registering students and printing name badges
- Special Events Coordinator for Society of Women Engineers (2016 – 2017)
 - o SWE 5K and Volleyball Tournament Coordinator
 - o Plan major events throughout the year and create and manage committees for those events
- Networking Night Coordinator (2016)
 - o Reached out to over 100 companies and communicated with them about registration
 - o Made company packets for event and advertised to students
- Program Sales Committee Chair (SWE career fair; 2015 – 2016)
 - o Organized volunteer times for program Pre-Sales, sold programs at the event, and managed money
- BuckeyeThon Team Captain (2015 – 2016)
 - o Set team goals, organized fundraisers and completed all team paperwork

SKILLS & RELATED COURSE WORK

- Software: MATLAB, C++ programming, SolidWorks, Microsoft Word, Excel, Project and PowerPoint
- Communication: Technical Writing, Engineering Ethics, Engineering Economics
- Courses: Soil and Water Engineering, Statics, Fluid Statics, Mechanics of Materials, Surveying, Thermodynamics, Heat and Mass Transfer, System Dynamics and Electricity, construction scheduling

PROJECT EXPERIENCE

Advanced Energy Vehicle Project (January – May 2015)

- Served as team leader for creating an energy efficient AEV that exceeded the operational requirements
- Managed schedule, recorded information at group meetings, and wrote group documents

COMMUNITY SERVICE PROJECTS

- First Lego League
 - o Mentor middle school children to perform at a high level in team competition
- Women in Engineering DREAM volunteering
 - o Group leader: mentoring young girls through engineering related activities

WORK EXPERIENCE

- Eaton, Nashville, TN
Technical Sales Intern, May – August 2018
 - o Lead rollout of new product, put together marketing packages, developed standardized methods
- Rusty Bucket, Columbus, OH
Server, August 2017 – present
- Aerie by American Eagle, Columbus, OH
Salesperson, October 2015 – April 2018

CHARLES YUHAS

Yuhus.18@osu.edu · (310) 489-1076

EDUCATION

The Ohio State University

Biological Systems Engineering: 2015- Present

Expected Graduation: Spring 2019

Santa Barbara City College

Engineering: 2013-2015

COURSEWORK & SKILLS

Coursework: Manufacturing Process Engineering, Chemical Process Engineering, Bioprocess Engineering, Materials Science

Programs/ Languages: Cross-platform OS knowledge, MATLAB, Simulink, Python, AutoCAD, SolidWorks, Microsoft Office

Skills: Metal Working, Surface Characterization, Material Testing of Solids, Injection Molding, Casting, Forging, Troubleshooting

EXPERIENCES

The Ohio State University · Student Life Technology Services · Columbus, OH

Client Services Student Lead · June, 2017 – Present

- Install, configure, and maintain computer workstations and servers in a Microsoft Windows environment
- Created automation batch and PowerShell scripts to improve deployment time by 55%
- Improved efficiency in the configuration of department equipment and settings
- Assist faculty, staff and students with acute technical issues, and troubleshoot and repair common issues
- Utilized Active Directory to verify machine status on domain, associated groups, and obtain BitLocker keys

Pacific Property Management · Business Owner · Columbus, OH

Property Manager · September, 2018 – Present

- Meet with prospective tenants to show properties and explain terms of occupancy
- Inspect grounds, facilities, and equipment routinely to determine necessity of repairs or maintenance.
- Maintain records of sales, rental or usage activity, maintenance and operating costs, or property availability
- Investigate complaints, disturbances and violations and resolve problems
- Direct collection of monthly assessments, rental fees, and deposit

The Ohio State University · Department of Recreational Sports · Columbus, OH

Facility Manager · July, 2016 – June, 2017 | *Facility Assistant* · September, 2015 – July, 2016

- Supervise assistants and assume responsibility for 60 acres of outdoor space and 20,000 square feet of indoor space
- Accountable for an average of 300 facility users a day, and resolve issues and disputes amongst patrons
- Responsible for training 18 Facility Assistants on daily operations and policies for multiple facilities

PROJECTS

Global Water Institute · Capstone Design · Columbus, OH

Software Engineer · August 2018 – May 2019

- Designed drone package to be deployed for agriculture consultants in the Singida region of Tanzania
- Developed program using Python to analyze crop field health using user-defined boundaries

Bioreactor Design Project · Columbus, OH

Chemical and Biological Engineering 5766 · August 2018 – December 2019

- Designed fermentation process to mass produce vanillin using *E. coli* and ferulic acid
- Proposed downstream and recovery process to synthesize vanillin

B - Full Listing of Drone Package Contents

Drone Package Includes:

- DJI Mavic Pro Drone with
- camera and gimbal
- 3 extra batteries
- 4 sets of propellers
- Remote control
- Car charging adapter
- Multi-battery dock
- Battery pack to DJI adapter
- Wall charger
- Cables to connect to phone (3 different phone types)
- Solar charging backpack
- Custom image analysis application
- Drone operation manual and code manual

Price Breakdown:

Item Name	Includes	Price
Drone Package (from Amazon)	DJI Mavic Pro drone, 3 batteries, 4 propellers, remote control, car charging adapter, multi-battery dock, battery pack to DJI adapter, wall charger, cables to connect to phone (3 different), operation manual	\$924.36
Solar Charging Backpack (from Amazon)	Backpack and adapters	\$299.00
Charging Cable	USB Male to Male Ends	\$20.00
	Total Spent:	\$1,243.36

C - Instructional Manuals

DRONE PACKAGE

Installation and User Instructions

Table of Contents

In the Box

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Aircraft

Remote Controller

Steps to Fly Drone

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Pre-flight Checklist

Before You Begin

Individual Parts

Product Care

Flight Condition Requirements

*Jenna Lee, Noah Veccia, Abigail Warburton,
Kathleen Whalen, Charles Yuhas*

Global Water Institute | OSU Capstone

In the Box



Aircraft



Remote Controller



Intelligent Flight
Battery



Battery Charger



Propeller Pairs



RC Cables



Power Cable



Micro USB Cable



microSD Card

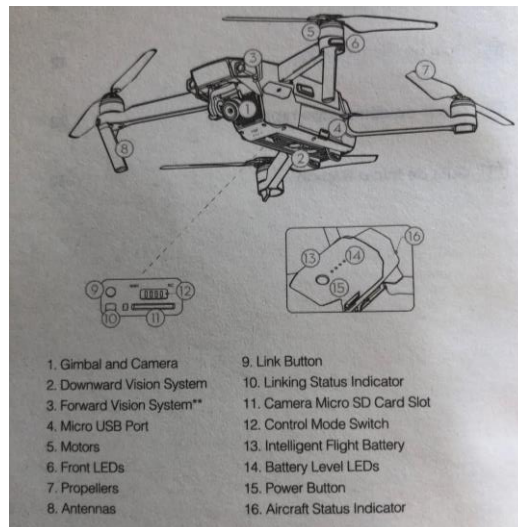


RC Cable Slider

Quick Start Guide

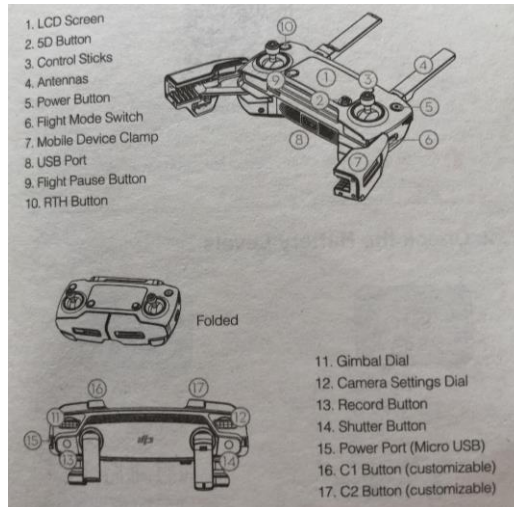
Aircraft

The DJI Mavic Pro features a fully stabilized camera, Intelligent Flight Modes and Obstacle Avoidance inside its folding design. The Mavic Pro captures 4K videos and 12 megapixel photos. It has a maximum flight speed of 40 miles per hour (65 kph) and a maximum flight time of 27 minutes.



Remote Controller

The remote controller has the latest long-range transmission technology offering a maximum transmission range of 4.3 miles (7km). To keep you updated on aircraft data there is an onboard LCD screen, and video from the aircraft to DJI GO 4 app on your mobile device up to 1080p at close range and 720p at longer ranges. Maximum run time is 2.5 hours.



Steps to Fly Drone

1. Download the DJI GO 4 App and Watch the Tutorial Videos
2. Check the Battery Levels
 - Press once to check the battery level. Press once, then again and hold to turn on/off.
3. Charge the Batteries
4. Prepare the Remote Controller
5. Prepare the Aircraft
 - Remove the gimbal clamp from the camera. Match propellers to motors. Press the propeller down firmly and rotate in the lock direction. Unfold the front and rear arms and the propellers.
6. Prepare for Takeoff
 - Power on the remote controller. Power on the aircraft. Launch the DJI GO 4 app.
7. Flight
 - The left stick controls the aircraft's altitude and heading. The right stick controls its forward, backward, left and right movements. The gimbal dial controls the camera's tilt.
8. Fly Safe
 - Fly in open areas. Strong GPS signal. Maintain line of sight. Fly below 400 feet.

Disclaimer and Safety Guidelines

Safety At a Glance

1. Environmental Considerations
 - Fly clear of buildings, obstacles, and large groups of people.
 - Avoid altitudes of above 400 feet (120 m).
 - Fly in moderate weather conditions.
2. Pre-Flight Checklist
 - Ensure the remote controller and aircraft batteries are fully charged.
 - Ensure the propellers are in good condition and securely tightened.
 - Ensure there is nothing obstructing the motors.
 - Only calibrate the compass when the DJI GO 4 app or the status indicator prompt you to do so.
 - Check that the camera lens is clean and free of stains.
3. Operation
 - Stay away from propellers and motor.
 - Maintain sight of aircraft.
 - DO NOT fly under influence of drugs or alcohol.
 - If Low Battery Warning occurs, land the aircraft in safe location.
4. Maintenance and Upkeep
 - DO NOT use chipped or broken propellers.
5. Observe Local Laws and Regulations
 - DO NOT fly in the No Fly Zones.
 - Avoid flying in areas where rescue teams are actively using the airspace.

Notice:

All instructions and other collateral documents are subject to change. For up-to-date product information, visit <https://www.dji.com> and click on the Mavic Pro product page.

Pre-flight Checklist

1. Make sure you are using genuine parts and all parts are in good condition.
2. Make sure the remote controller, intelligent Flight Battery, and mobile device are fully charged.
3. Make sure nothing is stuck to the camera lens, the Micro SD card has been inserted, and the gimbal can rotate freely before turning it on.
4. Make sure propellers are securely mounted onto the motors, and motors can function normally.
5. Follow the on-screen instructions to calibrate compass.
6. Make sure the app and firmware have been updated to latest version.
7. Confirm that you are not in a No Fly Zone and make sure flight conditions are suitable for flying aircraft.

8. Be sure to NOT fly under the influence of alcohol, drugs, or any other substance that could impair your cognitive abilities.
9. Be familiar with selected flight mode and make sure to understand all safety functions and warnings.
10. Be sure to observe regulations, obtain authorization if necessary, and understand risk.

Disclaimer and Warning:

This product is NOT a toy and is not suitable for children under the age of 18. This product is a flying camera that offers easy flight when in good working order. By using this product, you agree that you are solely responsible for your own conduct while using this product, and for any consequences thereof. You agree to use this product only for purposes that are proper and in accordance with all applicable laws, rules, and regulations, including international and domestic airspace regulations.

DJI or GWI accepts no liability for damage, injury or any legal responsibility incurred directly or indirectly from the use of this product. The user shall observe safe and lawful practices including, but not limited to, those set forth in these Safety Guidelines.

Before You Begin

The following documents have been produced to help you safely operate and make full use of your Mavic Pro:

In the Box

Disclaimer and Safety Guidelines

Intelligent Flight Battery Safety Guidelines

Quick Start Guide

User Manual

Individual Parts

Regarding Genuine and Functional Parts

Warning:

To avoid component malfunction, injury, and property damage, observe the following rules:

1. Use only DJI parts or parts certified by DJI.
2. Ensure there are no foreign objects inside of the aircraft or its components.
3. Ensure the aircraft and its components are all in good working order, damage-free, and functioning well.

Remote Controller

Notice:

1. Ensure the remote controller is fully charged before flight.

2. If the remote is power on and has NOT been used for 5 minutes, it will sound an alarm. After 10 minutes, it will automatically power off. Move the sticks or perform some action to cancel the alert.
3. Adjust the clamp of the mobile device holder to allow a firm grip on device.
4. Ensure mobile device holder is firmly in place.
5. Ensure the antennas of the remote controller are unfolded and adjusted to the proper position to achieve optimal transmission quality.
6. Repair or replace the remote controller if damaged.
7. Linking is required if you wish to replace your remote controller or receiver.
8. Fully charge the battery at least once every three months to maintain battery health.

Camera

Caution:

To avoid possible injury and property damage DO NOT block any ventilation holes on the camera as the heat generated may hurt you and damage the device.

Notice:

1. Check camera settings before use to make sure you can adjust them to fit your needs.
2. Test the camera and check that it is operating correctly.
3. DO NOT remove the Micro SD card from the camera when it is powered on.
4. Photos or videos cannot be transmitted or copied from the camera if the Intelligent Flight Battery is powered off.
5. Be sure to power off the Intelligent Flight Battery correctly, otherwise your camera parameters will NOT be saved and any recorded videos may be damaged.

Gimbal

Notice:

1. Precision elements in the gimbal may be damaged in a collision or impact.
2. DO NOT apply external force to the gimbal after the gimbal is powered on.
3. DO NOT add any payloads to the gimbal.
4. Remove the gimbal clamp before powering on the gimbal. Re-install the gimbal clamp to secure the gimbal's position.

Compass

Caution:

Land immediately when severe drifting occurs in flight, i.e., the aircraft does NOT fly in straight lines.

Notice:

Only calibrate the compass when the DJI GO 4 app or the status indicator prompt you to do so. Observe the following rules when calibrating your compass:

1. DO NOT calibrate where there is a change of strong magnetic interference, such as magnetite, parking structures, and steel reinforcements underground.

2. DO NOT carry ferromagnetic materials with you during calibration, such as cell phones.

Propulsion Systems

Warning:

Propellers

1. DO NOT use aged, chipped, or broken propellers.
2. Always power off the aircraft before touching the propellers.
3. Be aware of the sharp edges of the propellers when mounting or removing the propellers.
4. Whenever necessary, use tools to remove or install the propellers.
5. Ensure the propellers are securely mounted to prevent them from falling off the motors.
6. DO NOT turn on the motors when propellers are mounted and there are other people or animals in the immediate vicinity.

Motors

1. Ensure the motors are securely mounted and rotating smoothly.
2. DO NOT attempt to modify the structure of the motors.
3. DO NOT touch or let your hands or body come in contact with the motors after flight as they may be hot.

Caution:

DO NOT block any of the ventilation holes on the motors and DO NOT block any of the ventilation holes on the body of the aircraft.

Notice:

Motors

1. Keep motors free of dust.
2. If a motor is stuck and unable to rotate freely, stop the motors immediately.

Electronic Speed Controllers

1. Ensure the ESEs sound a normal tune when powered on.

App

Notice:

1. Be sure to fully charge your mobile device before launching the app.
2. If you are using a phone as your mobile display device, be sure to continue flying safely when the phone receives an incoming call. DO NOT accept phone calls during flight.
3. Read all prompted safety tips, warning messages, and disclaimers carefully.
4. Land your aircraft immediately if there is an alert shown on the app.
5. Examine and check all warning messages on the checklist displayed in the app.
6. Use the in-app simulator to practice your flight skills.

7. Beginner mode is enabled by default when you launch the app for the first time. Operate the actual aircraft only after you are confident that you have mastered adequate flight skills.
8. Cache the map data of the area where you intend to fly the aircraft by connecting to the internet before each flight.

Firmware

Warning:

Keep children and animals at a safe distance during any firmware upgrade, system calibration, and parameter setting procedures.

Notice:

1. For safety, always update the firmware to the latest version when an upgrade notification is shown in the app.
2. Firmware upgrade notifications will prompt you to proceed with an update immediately or to update the firmware within three days.
3. Be sure to download the firmware package file from the official DJI website.
4. Be sure to update the remote controller's firmware to the latest version after you updated the aircraft's firmware.
5. The remote controller may become unlinked from the aircraft after updating.
6. Be sure to check all connections and remove the propellers from the motors before performing firmware updates.

Internal Storage Device

Notice:

1. The aircraft contains an internal storage device that may store data and operations records. Still and motion imagery data may be automatically generated from the one or more sensors when you operate the aircraft.
2. Due to the potentially automatic generation of imagery data by the aircraft during operation, DO NOT operate the aircraft in areas where people may reasonably expect privacy.

Product Care

Storage and Transportation

Warning:

Small parts, such as cables and straps, are dangerous if swallowed. Keep all parts out of reach of children and animals.

Notice:

1. Store the Intelligent Flight Battery and remote controller in a cool, dry place away from direct sunlight to ensure the built-in LiPo battery does NOT overheat.

2. DO NOT allow the camera to come into contact with, or become immersed in, water or other liquids. If it gets wet, wipe dry with soft, absorbent cloth. DO NOT store in humid or dusty areas.
3. DO NOT connect this product to any USB interface that is older than version 2.0.

Maintenance and Upkeep

Notice:

1. Check every part of the aircraft after any crash or violent impact.
2. Regularly check the Battery Level Indicators to see the current battery level and overall battery life.

Flight Condition Requirements

Weather Conditions and Surrounding Environment

Warning:

The aircraft is designed to operate in good to moderate weather conditions.

1. DO NOT use the aircraft in severe weather conditions.
2. Keep the aircraft at least 10 meters away from obstacles, people, animals, buildings, public infrastructure, trees, and bodies of water.
3. Be extra cautious when operating aircraft indoors.

Notice:

1. Aircraft and battery performance is subject to environmental factors such as air density and temperature.
2. DO NOT use the aircraft near accidents, fire, explosions, floods, tsunamis, avalanches, landslides, earthquakes, dust, or sandstorms.

Interface with Flight Controller, Communications, and Positioning Systems

Notice:

1. Fly in open areas.
2. Avoid interference between the remote controller and other wireless equipment.
3. DO NOT fly near areas with magnetic or radio interference.

Operating the Aircraft Responsibly

Warning:

1. Make sure you are NOT drunk, taking drugs, under the influence of anesthesia, or suffering from dizziness, fatigue, nausea or any other conditions.
2. Upon landing, power off the aircraft first, then switch off the remote controller.
3. DO NOT drop, launch, fire or otherwise project any dangerous payloads on or at any buildings, persons or animals, or which could cause personal injury or property damage.

Flight Modes, Functions and Warnings

Flight Modes

Warning:

DO NOT switch from P-mode to S-mode unless you are sufficiently familiar with the aircraft's behavior for each flight mode.

Notice:

1. P-mode: works best when the GPS signal is strong. The aircraft utilizes the GPS and Obstacle Sensing System to automatically stabilize itself, navigate between obstacles or track a moving object.
2. S-mode: identical to P-mode in terms of GPS settings, however, the Obstacle Sensing System is disabled.

Low Battery

Notice:

1. When the Critical Battery Level Warning activates and the aircraft is descending automatically, you may push the throttle up to maintain the aircraft's altitude and navigate it to a more appropriate location for landing.
2. When battery warnings are triggered, promptly bring the aircraft back to the Home Point or land to avoid losing power during flight and causing damage to the aircraft.

MAVIC Pro - Intelligent Flight Battery Safety Guidelines:

Battery Use

Warning:

1. DO NOT let batteries come in contact with liquid, could lead to explosion.
2. Only use DJI batteries for device and never used damaged batteries.
3. Only install and remove batteries when craft is turned off.
4. DO NOT use batteries in temperature above 50⁰C and below -10⁰C.
5. Use batteries in environment with no electrostatic/electromagnetic interference.
6. Never disassemble battery.
7. If electrolytes in battery come in contact with skin, eyes, etc. wash immediately for 15 minutes then consult doctor.
8. DO NOT put batteries in oven or pressurized container or place battery cells on conductive surface.
9. Avoid dropping batteries.
10. Clean battery terminals with clean, dry cloth.

Notice:

1. Charge battery fully before flight and when battery is low, land craft immediately to avoid damage

Battery Charging

Warning:

1. Use DJI adapter when charging batteries and never leave battery unattended while charging.

2. DO NOT charge near flammable liquids.
3. DO NOT charge battery right after flight, because battery may be too hot. Wait until it is cooled to room temperature.
4. Disconnect charger when not in use and never use damaged charger.

Notice:

1. Charger is designed to stop when battery is fully charged, but always unplug from charger when fully charged.
2. Keep Intelligent Light Battery turned off while charging.

Battery Storage

Warning:

1. Keep out of reach of children and pets.
2. Ideally, store at temperature between 22°C-28°C.
3. Keep dry, do not drop and keep away from metal objects.
4. Do not transport damaged battery or battery with power level higher than 5%.

Notice:

1. Discharge battery 45%-60% if battery will not be used for 10 or more days.
2. Battery automatically discharges to 65% and heating often happens during this.
3. Battery automatically goes into hibernation mode if not used for a long period. Refer to manual to bring it out of hibernation.
4. Remove batteries from aircraft when stored for long periods of time.

Battery Disposal

Warning:

1. Dispose of battery in proper disposal can, refer to local disposal guidelines.

Notice:

1. If battery cannot be turned off contact proper authority for disposal.

Battery Maintenance

Warning:

1. Do not use battery when temperature too high or too low and always store battery at proper temperatures.

Notice:

1. Never over-discharge, can lead to damage and battery use can decrease if not used in a long time.
2. Fully charge every 3 months to maintain battery.

Travel Notice

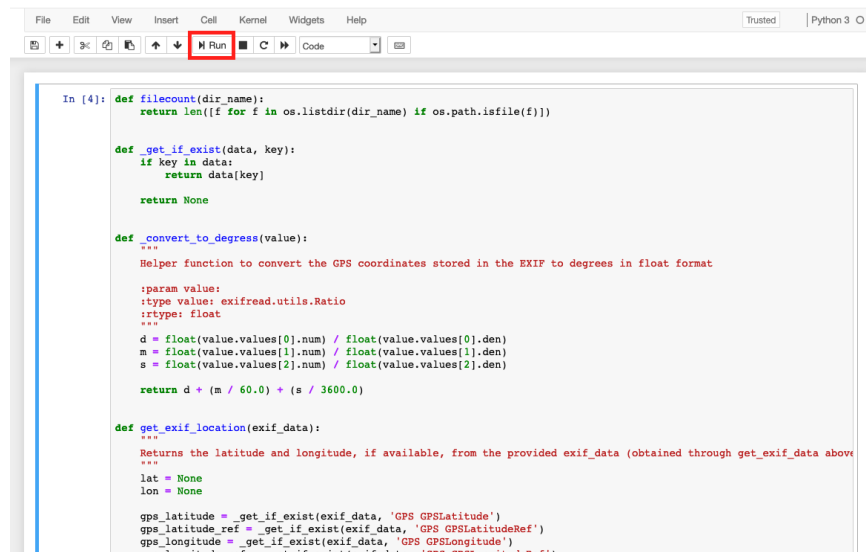
Warning:

1. Before taking battery in flight, it MUST be discharged by using it in the aircraft.

Notice: Store batteries in ventilated location.

The instructions for the program are as follows:

1. Run the program



```
In [4]: def filecount(dir_name):
        return len([f for f in os.listdir(dir_name) if os.path.isfile(f)])

def _get_if_exist(data, key):
    if key in data:
        return data[key]
    return None

def _convert_to_degrees(value):
    """
    Helper function to convert the GPS coordinates stored in the EXIF to degrees in float format

    :param value:
    :type value: exifread.utils.Ratio
    :rtype: float
    """
    d = float(value.values[0].num) / float(value.values[0].den)
    m = float(value.values[1].num) / float(value.values[1].den)
    s = float(value.values[2].num) / float(value.values[2].den)

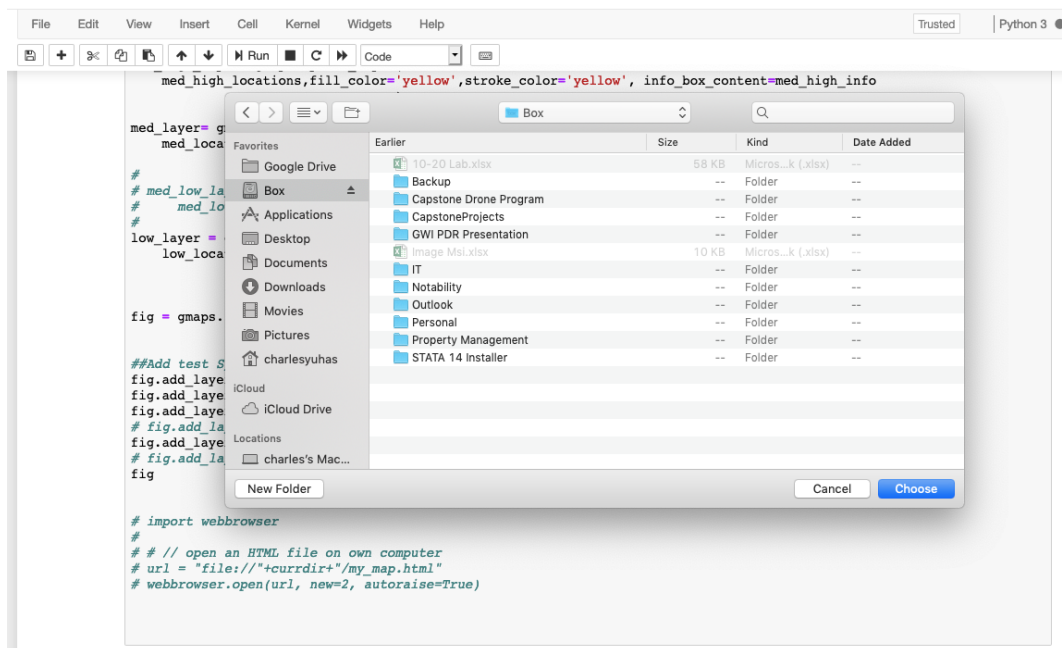
    return d + (m / 60.0) + (s / 3600.0)

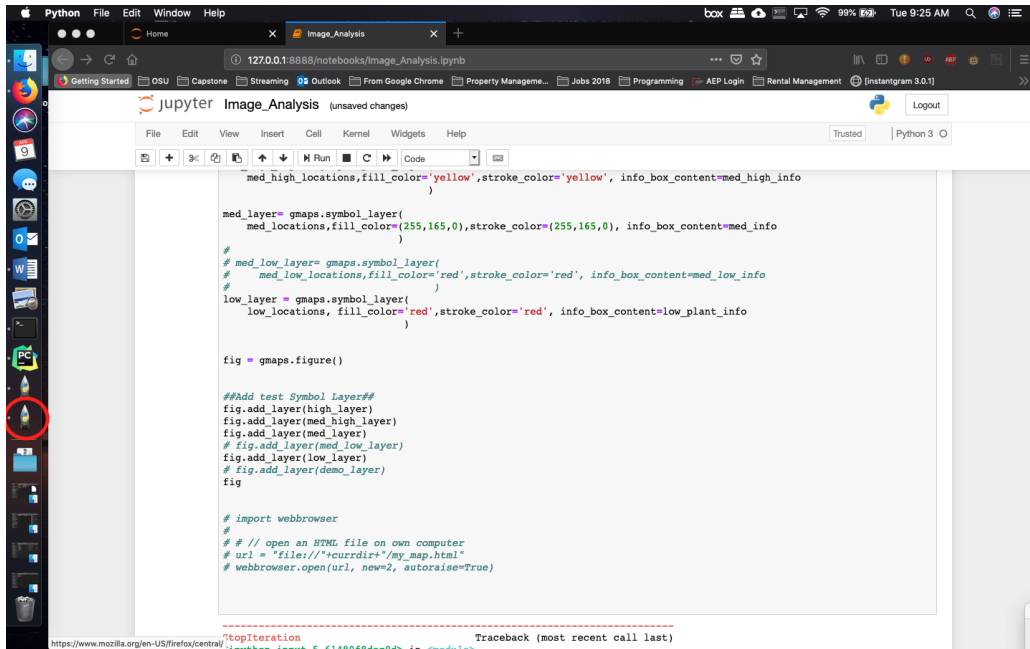
def get_exif_location(exif_data):
    """
    Returns the latitude and longitude, if available, from the provided exif_data (obtained through get_exif_data above)
    """
    lat = None
    lon = None

    gps_latitude = _get_if_exist(exif_data, 'GPS GPSLatitude')
    gps_latitude_ref = _get_if_exist(exif_data, 'GPS GPSLatitudeRef')
    gps_longitude = _get_if_exist(exif_data, 'GPS GPSLongitude')
    gps_longitude_ref = _get_if_exist(exif_data, 'GPS GPSLongitudeRef')
```

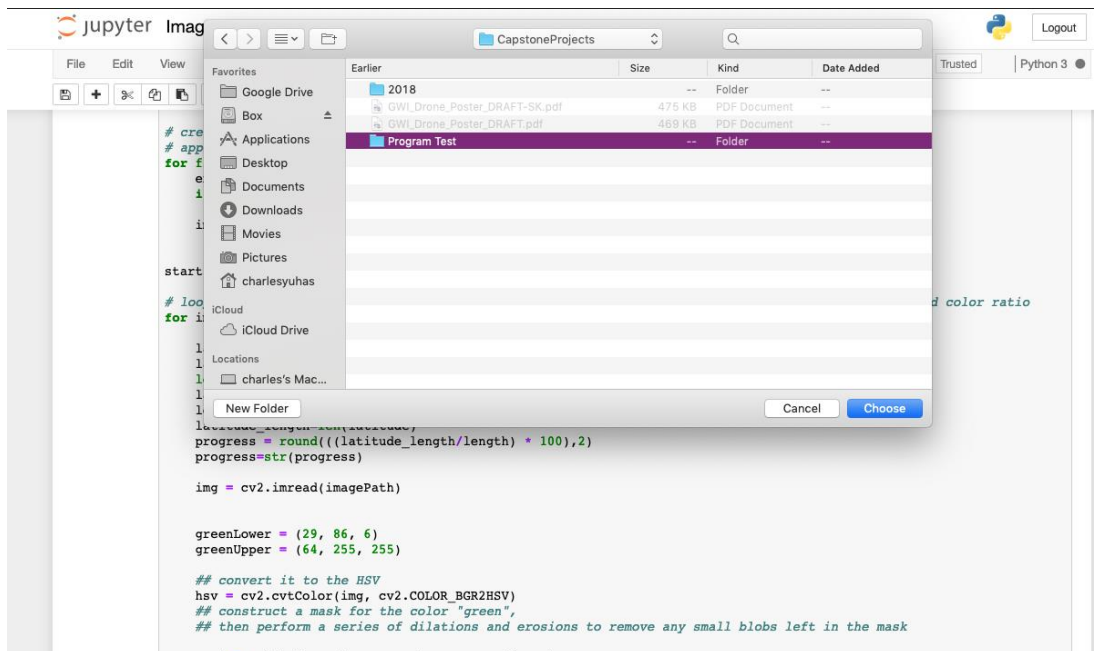
a. To run the program, select the “Run” option located in the top bar.

2. User will be prompted to select a folder to have analyzed





If a popup window does not automatically display, user must select the Python window as highlighted in the image above



**Program will only analyze images in the folder selected. If there are other folders inside the specified directory, the program will not select those images.

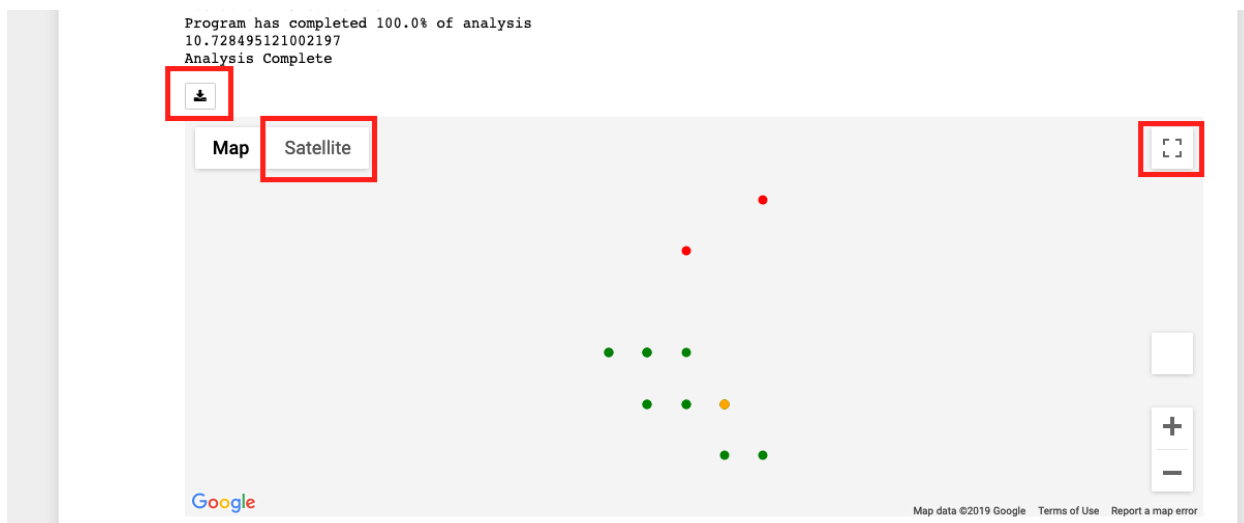
3. Wait for program to process the images

```
jupyter Image_Analysis (unsaved changes) Python 3 O
File Edit View Insert Cell Kernel Widgets Help Trusted Python 3 O
You chose /Users/charlesvuhlas/Box/CapstoneProjects/Program Test
Iteration: 1 out of 19
Program has completed 5.26% of analysis
Iteration: 2 out of 19
Program has completed 10.53% of analysis
Iteration: 3 out of 19
Program has completed 15.79% of analysis
Iteration: 4 out of 19
Program has completed 21.05% of analysis
Iteration: 5 out of 19
Program has completed 26.32% of analysis
Iteration: 6 out of 19
Program has completed 31.58% of analysis
Iteration: 7 out of 19
Program has completed 36.84% of analysis
Iteration: 8 out of 19
Program has completed 42.11% of analysis
Iteration: 9 out of 19
Program has completed 47.37% of analysis
Iteration: 10 out of 19
Program has completed 52.63% of analysis
Iteration: 11 out of 19
Program has completed 57.89% of analysis
Iteration: 12 out of 19
Program has completed 63.16% of analysis
Iteration: 13 out of 19
Program has completed 68.42% of analysis
Iteration: 14 out of 19
Program has completed 73.68% of analysis
Iteration: 15 out of 19
Program has completed 78.95% of analysis
Iteration: 16 out of 19
Program has completed 84.21% of analysis
Iteration: 17 out of 19
Program has completed 89.47% of analysis
Iteration: 18 out of 19
Program has completed 94.74% of analysis
Iteration: 19 out of 19
Program has completed 100.0% of analysis
```

**Output will display which folder was selected, how many files are in the folder, and what iteration the process is on. When analysis is complete, the user will see a output string of "Analysis Complete"*

4. Map will open with images plotted as points on map. There are 4 colors that could be displayed. This example only displays 3 colors.

Green = Good; Yellow = Fair; Orange = Poor; Red = Very Poor



5. User can click on points displayed on map to view latitude and longitude degree values on map



D – Printout of Program Code

To view a PDF version of the program code, visit the following link:

<https://osu.box.com/s/48ey5am16waocmk03hdt7rcj4p51i03d>