CONCEPTUALIZATION OF UAV BASED WAYPOINT GENERATION FOR PRECISION HORTICULTURE

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ABSTRACT

In the recent past, precision agriculture has proven to be an effective means for farmers to optimize productions by reducing efforts and losses. Usage of UAV has proven to be beneficial for large scale agriculture. The applications of UAV in small scale agriculture and horticulture has certain limitations due to the scale and elevation variations. The current paper aims at conceptualizing a novel remote sensing-based framework for optimizing spraying locations and heights for horticulture. The data used constitutes of DEM and visual images captured from UAV platform. The paper also covers a small use-case for coconut tree plantation for implementation and validation. The results suggest that implementation of such algorithm may help in reducing wastage of spraying chemicals and in-turn will reduce adverse environmental impacts of spraying. Further integrating current work with UAV systems for optimization of path will improve UAV efficiency.

Index Terms— UAV, DEM, Way-point, Remote Sensing, precision agriculture, horticulture

1. INTRODUCTION

Farmers and farm workers are known to suffer from Acute Pesticide Poisoning (APP) due to exposure to pesticides and insecticides and lack of safe equipment [1]. Usage of UAV has proven to be beneficial for large scale precision agriculture and for spraying pesticides [2], [3], [4]. This approach provides a much safer and exposure free procedure. However, when it comes to spraying trees, use of UAVs is limited due to the varying heights of the trees. Moreover, unlike a crop field, the spacing and distribution is not uniform either. Although spraying from the maximum possible height is feasible, its avoided due to excessive consumption of pesticide as well as environmental impacts. But, if the position and height of each tree is known, it is possible to generate 3D waypoints for the UAV to fly through, only spraying from fixed altitude above each tree. This paper proposes a framework to utilize high resolution digital elevation models (DEMs) to extract elevation information of point of interests (POI), in this case trees, to generate the data needed for a precise flight plan.

2. OBJECTIVE

This paper aims at conceptualizing a framework for generating waypoints for optimizing spraying operations for precision horticulture using UAV remote sensing techniques. The proposed framework aims to use mapping UAVs and existing open source software to provide a spraying plan for precision horticulture using UAVs.

3. PROPOSED FRAMEWORK

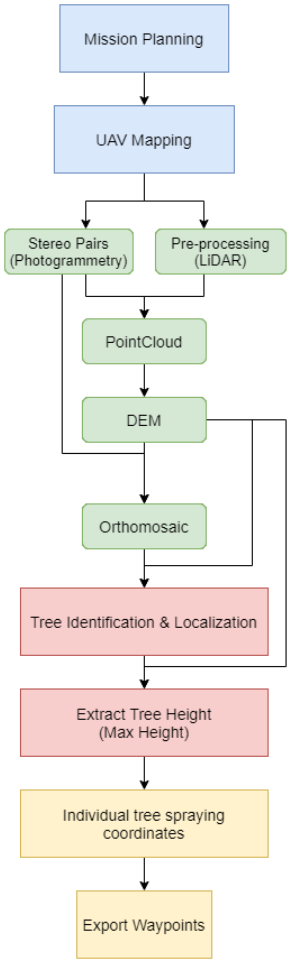

Fig. 1. Framework Flowchart

Fig. 1 shows the flowchart for the proposed framework. The flowchart mainly constitutes of four parts. The first two talk about base data preparation, the third part talks about pre-processing and the last part talks about waypoint generation.

3.1 Base Data Preparation

A UAV can be used to collect aerial images of the area encompassing the trees that need to be sprayed. The images then need to be aligned based on their location and altitude. This can be done using existing mapping software. The aligned photos can then be used to generate a pointcloud as seen in Fig. 2 which is necessary for extracting elevation information of trees. This pointcloud can then be used to generate an orthomosaic and a DEM of the surveyed area.

Fig. 2. Sample Pointcloud

The generated pointcloud will give us elevation information of each point on the ground (according to the ground sampling distance).

The generated orthomosaic and DEMs are required for localization of trees in 3D space. DEMs contain elevation information whereas orthomosaics are necessary for detection and localization of trees.

3.2 Pre-processing

Once an orthomosaic and DEM is available, object detection algorithms such as single shot detector (SSD) can be used to detect the desired types of trees in the orthomosaic [5]. Orthomosaics are orthorectified meaning they follow a map projection. This helps in localizing the detected trees and provides the location of trees in the form of coordinates.

The locations generated by tree detection algorithm can be used to find the elevation of the tree. This can be achieved by using pixel mapping of orthomosaics and digital elevation models.

The tree detection algorithms can also use DEM data to improve accuracy by considering the 3D shape of the tree canopy.

3.3 Waypoint Generation

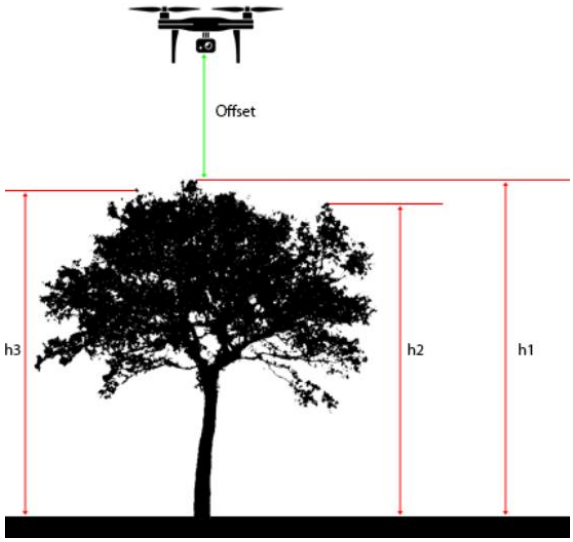

Fig. 3. Height Estimation

Fig. 3 illustrates a scenario of calculation of height of each waypoint. The coordinates provided by the localization algorithm can be used to calculate the height of each waypoint based on the equation given below.

$$Waypoint_{Height} = MAX(h1, h2, h3 \ldots . hn) + Offset$$

Here h1, h2 and h3 are heights of the points from the ground as seen in Fig. 3. The waypoint height is calculated by taking a max of all the heights and adding the offset height. For ideal results evenly distributed points on the DEM must be considered for calculating heights (h_i). More than three heights (h_i) need to be considered for higher accuracy.

The offset height is the distance between the highest point of the tree and the nozzle of the spraying UAV. The offset is required to ensure an even distribution in spraying which is decided based on specific tree requirement by consulting an agriculture expert.

4. RESULTS AND DISCUSSION

The expected results are discussed in this section. Some preliminary results from ongoing work show the efficacy of developing a system capable of achieving high precision while being efficient and reliable.

4.1 Orthomosaics and DEMs

Fig. 4 shows a sample orthomosaic generated using aerial images taken with a UAV. The orthomosaic has a resolution or GSD (ground sampling distance) of 2.8 cm/pixel. The orthomosaic shows a farm with various trees and fields. Similarly, Fig. 5 is a digital elevation model of the same farm

seen in Fig. 4 generated using the same raw data. The DEM can have a GSD in the range 2 - 30 cm/pixel which results in resolutions considerably higher than those of DEMs generated by satellites such as NASA's SRTM with 30 - 90m and WorldView with 0.5m resolution [6],[7]. These samples show the high resolutions made possible by UAVs and can be used to detect and localize trees and other points of interest.

Fig. 4. Sample Orthomosaic

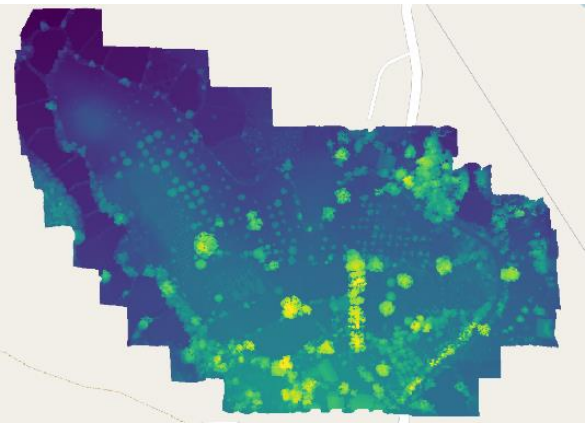

Fig. 5. Sample DEM

4.2 Detection and Localization

Fig. 6 shows a sample implementation of an object detection and localization algorithm. The result demonstrates the efficacy of developing a useable system. Fig. 6b shows the heights (max height) of coconut trees that are detected using orthomosaics, which are seen in Fig. 6a. SSD which is a deep network-based object detector was used to detect coconut trees as seen in Fig. 6a along with the confidence levels. The implemented algorithm demonstrates the feasibility of using object detection algorithms for tree localization.

Fig. 6a. Tree Localization

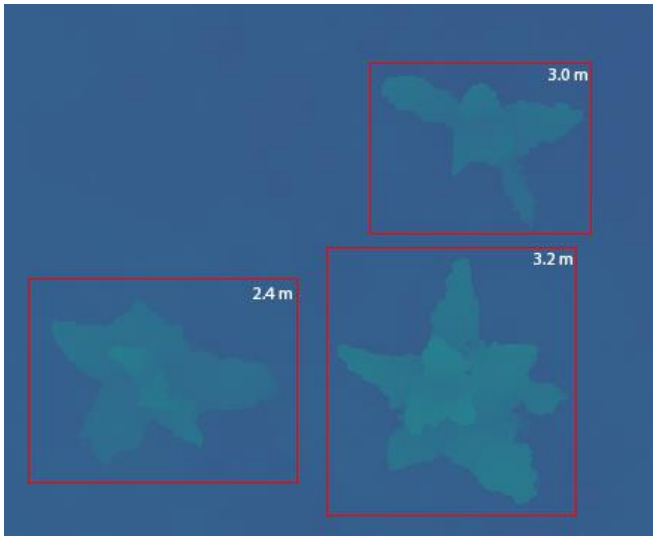

Fig. 6b. Height Estimation

4.3 Waypoint Generation

Table 1. Sample Output

Sr No.	Latitude	Longitude	Spraying Altitude (AGL)
1	Lat_1	Lon_1	Alt_1
2	Lat_2	Lon_2	Alt_2
3	Lat_3	Lon_3	Alt_3
4	Lat_4	Lon_4	Alt_4
5	Lat_5	Lon_5	Alt_5

The generated waypoints can be stored in a universal format such as comma separated values (CSV) as seen in table 1. This makes it convenient for use with most systems.

5. FUTURE WORK

1. The efficiency and optimality of generating DEMs from various sources for conceptualized framework can be tested.
2. Alternate methods of plant height estimation can be explored, and their efficacy can be evaluated [8].
3. Machine learning can be implemented for detecting and localizing trees in Orthomosaics and DEMs [9]. This process is in development and being tested on coconut trees using the SSD [5].
4. Different trees have differently sized canopies and hence need to be sprayed from varying heights for efficient canopy coverage. Canopy size can be analyzed to achieve the same for maximum spraying efficiency.
5. An optimal flight path can be planned after generating waypoints to minimize the total time taken to spray the entire orchard or selected trees. This flight path can also be optimized to avoid obstacles [10].

6. CONCLUSIONS

This paper conceptualizes a framework for generating waypoints for optimizing spraying operations for precision horticulture using UAV remote sensing techniques. The paper discusses the feasibility of developing such a system. The preliminary results from ongoing work show that the proposed framework can be implemented in its entirety.

The orthomosaics and DEMs generated using UAV mapping have the advantage over traditional methods in terms of high resolution. Implementation of a simple object detection algorithm demonstrates the efficiency based on results seen in Fig. 6a of detecting and localizing trees from orthomosaics and DEMs.

As discussed in the previous section, this paper is a presentation of ongoing work and only proposes a framework. The framework needs to be implemented and tested in real world scenarios to estimate precision and reliability. Furthermore, flight path and waypoint generation methods need to be optimized to generate efficient paths.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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