Design Autonomous Drone Control For Monitoring Tea Plantation Using Dynamic Programming and Kruskal Algorithm

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***Abstract*— Indonesia is a country with the largest tea producers in the world, with a very large area needed tools to be able to help monitor the area of tea plantations as a whole. Unmanned Aerial Vehicle (UAV) wash chosen as a solution for the monitoring proses. Optimum flight path calculation is needed in order to produce good quality images, and also it influence to power consumption. The algorithm proposed in this study is Dynamic Programming and Kruskal Algorithm. Implementing these two network algorithms is expected to find the optimal path in aerial photography. The experimental results showed that the algorithm produced the optimum path , and more efficient power consumption than conventional lines. Image data obtained during tea plantation monitoring produced high-quality images, with the accuracy of each map above 90% and the assumption of errors below 5%.**

Keywords—*Unmanned Aerial Vehicle UAV, Monitoring, Dynamic Programming, Kruskal, Mapping.*

I. INTRODUCTION

Design autonomous drone control for tea Plantation is a technique of monitoring plantations, especially tea using Unmanned Aerial Vehicle (UAV) or drones by displaying an object that will be monitored, namely tea leaves from above the air.

Currently monitoring of plants, especially tea leaves, is still done manually where the foreman as supervisor of each garden block will go directly to the field to observe the condition of tea leaves. In manual monitoring problems often occur, such as uneven leaf color maturity, and tree loss which results in a decrease in the quality and quantity of tea plantations. But with the development of technology now things like that can be monitored more easily in real time, one of which uses UAV or drones. In addition, tea plantations also need a control system to assist UAV in determining the monitoring path and analyzing the results of monitoring the tea gardens [1] [2].

The purpose of this study was to create a UAV system to monitor tea leaves with low power consumption. For that we use the D-Jing Innovations Science and Technology (DJI) Phantom 4 type Quadcopter, which has 4 propellers as a driver. The UAV will be flown to the tea garden area, then the UAV will take data in the form of photos, from each appropriate point, the results of the image will be processed into maps [3].

Maximum 100 Mbps Video Bitrate is required, with a resolution of 4096 x 2160 images from a UAV to a high control center needed both in sending data between UAVs and vice versa. However, the standard for wireless communication services is the 2.4GHz frequency. In addition, low power consumption is needed in this study, the DJI Phantom 4 can survive in the air for 30 minutes. It is expected that UAVs can last less than 30 minutes to retrieve data on an area of 20ha [4].

Graph theory in the network is a candidate to find a solution to the requirements mentioned above. The Drone system used is Line of Sight (LOS), where the Drone will later use the Global Position System (GPS) as a guide in carrying out the mission. The research problem is how to find the picture in air with optimum path to take picture with the measured parameter is power consumption. Drones may not be form cycles and loops in data retrieval. There is 1 block of tea plantation, where 1 block will be measured in an area of 20ha, in this study the UAV will work in block 7 of the Indonesia Tea and Chinchona Research Insitute (Pusat Penelitian Teh dan Kina, PPTK) Bandung, Ciwidey. The effects of coverage and range will ensure that the UAV can work properly. In this research the UAV will work in the 2.4 GHz frequency range, using the DJI Phantom 4 which functions UAV as a monitoring tool [4].

The main objective of this research is to realize an UAV that can automatically monitor tea plantation land, by using algorithms, Dynamic Programing and Kruskal as the basis for calculations, with the following parameters:

1. Makes the UAV work automatically to move point to point.
2. Finding the optimal path and energy efficiency for taking pictures in the air, with measured parameters is power. The coverage area of the image generated from monitoring, must have an accuracy above 95% assuming errors below 5% and power must be efficient after calculation.
3. Compare the results of the image after the calculation using dynamic programming and the kruskal algorithm. The final image produced must be acceptable compared to the previous data.

This paper is organized as follows: Part II Study Area and Data Used during the study. Part III presents the design of the flight path of a drone using the calculation of Dynamic Programming and Kruskal algorithm. Part IV presents the optimum path results, power consumption and the proposed map. Finally, Part V concludes the paper.

II. METHOD

Monitoring is a system of collecting data or information on a regular and continuous basis, which can be generated by indicators of development and achievement of an activity or program activity against the objectives set[5]. The monitoring system includes identifying problems that occur from the monitored area. Tea plantation monitoring starts from creating a control system, while the UAV that will be implemented is the DJI Phantom 4 which functions remotely transferred to a smartphone connected by GPS to control the path of the drone.

Monitoring can help the interests of planters, especially in the field of tea gardens. Control of UAVs to monitor plantations has the potential to help farmers monitor the growth of tea leaves directly from the air. The place of case study was conducted in Gambung, Ciwidey, West Java province, Indonesia. The study area chosen for this work has an area of 20ha for testing. This research serves to monitor the tea plantation area there [6] [7].

A. Android App

We developed an android application that utilizes the development of the DJI soft drive (SDK) to control drones in performing actions that will be given at different heights. At present, there is no open source android application that allows to install drones for automatic control needed in our experiments. Although most of these applications are built from the existing DJI demo application, we have to develop a number of key components including controlling the drone that originally used a joystick from the remote now changed and replaced with a smartphone.The following are the functions that will be applied in the application. Fig 1 shows the application applied in the smartphone. The following are the functions of each button:

- Locate: The function of this button will show the location of the drone on the Google map. and Every drone movement can monitor on Google maps.

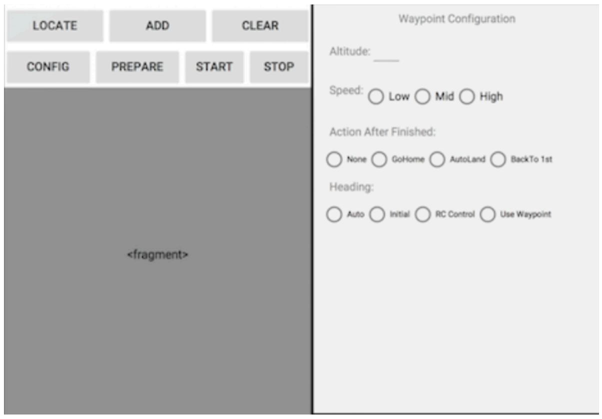

Fig. 1. Screenshot of the function app

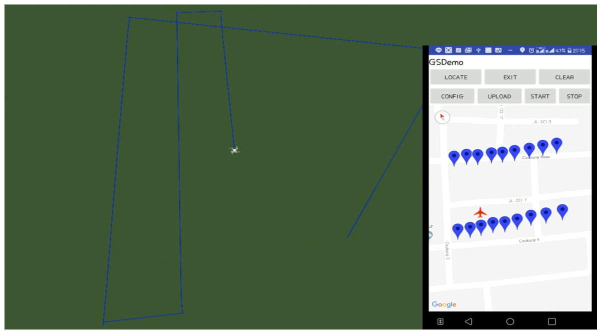

Fig. 2. Screenshot of Simulation

- Config : The function of this button is to set the drone from height to speed that will be used before running.
- Add: The function of this button will later indicate the waypoint the path that the drone will pass.
- Upload : The function of this upload is to upload the pre-set mission to the drone, so that the drone gets the track that has been uploaded.
- Start and Stop : The function of this button is to start running missions and stop missions.

B. DJI Simulator

DJI provides a drone simulator that allows you to test the results of modification of the application. In the simulation, the autonomous drone design will be tested to order before being released in the field. We use the DJI simulator along with the Android application to test the drones to follow movements that are designed and collect data show in fig 2.

III. SYSTEM DESIGN

Controlling the movement of the drone in accordance with the commands given from the software. In fig 2 you can see the control system used by changing the function of the remote control into a smartphone, this control system is useful for finding paths for shooting tea leaves in the air.

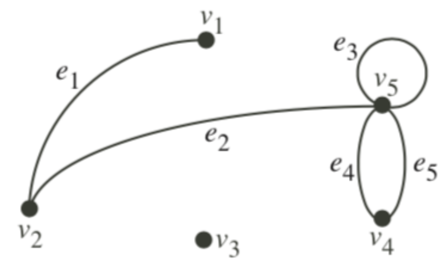

Fig. 3. Label Graph

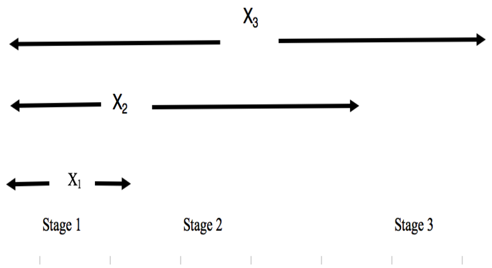

Fig. 4. Initial Stage

UAV with high resolution cameras are flown at 3 different heights. The captured images are then processed using agisoft software with the stiching method so that the results of the images are maps with the coordinates of each image [6]. The initial data is taken on a path based on the radius of the camera. To take the initial data we try to 10 times from each height. The results of the initial data will be calculated using Dynamic Programing and the Kruskal algorithm, both algorithms are used as calculations to find the op,mal path in shooting and determine efficient power consumption.

In Fig 3 you can see a graph set (e, v) where V is a set of vertices and (e) is a set of edges, connected by a pair of vertices. $(e)$is an advantage, thus, elements that can occur more than once so that each element has multiplicity. Verticals are often labeled a, b, c, .$v1$,$v2$ or numbers 1 and 2 in the example used are $v1$ and $v2$ but in later research we will give the symbol number 1,2 and so on from the node which will later become the waypoint.

$$we\ have\ V = \{v_0, \ldots, v_7\} for\ the\ vertices \quad (1)$$

$$E = \{(v_0, v_1), (v_2, v_5), (v_6, v_7)\} for\ the\ edges \quad (2)$$

A. Principle of optimization

- In dynamic programs, the optimal set of decisions is made using the Optimality Principle.
- Principle of Optimality: if the total solution is optimal, then the part of the solution to the to-k stage is also optimal.
- The principle of optimality means that if we work from stage k to stage k + 1, we can use the optimal results of stage k without having to go back to the initial stage.
- The cost of the step to +1 = (the cost generated in step k) + (the cost from stage k to stage k + 1).

Characteristics of Dynamic Program Problems Dynamic programs can be divided into several stages show in fig. 4, at which one decision is only taken. One decision is a conclusion of some of the results that have been obtained in the calculation. Each stage consists of a number of states related to that stage.

Stage (k) is the process of selecting the next destination node (Total stages). While the status (s) corresponding to each stage are vertices in the graph.

The following repeating relation states the shortest path from status s to x_4 at stage k:

$$f_4(s) = C_{sxN}(base) \quad (3)$$

$$f_k(s) = \min_{x_k} \left\{ C_{sxk} + f_{k+1(X_k)} \right\} (recurrence) \quad (4)$$

$$k = 1.2.3 \quad (5)$$

Information:

- k_k : Variable decision at stage k (k=1.2.3)
- C_{sxN} : Side weight (cost) from s to x_k
- f_k (s,x_k) :Total track weight from s to x_k
- f_k (s) Minimum cost to f_k (s,x_k)

B. Mapping

In this stage is the process of merging or stitching, in this process the results of the images taken by the drone will be combined into a map of the area being monitored.

$$Absolute\ Error => 5\%\ of\ 20ha = 10000m^2$$

$$Percentage\ Error = \frac{Assuming\ an\ error}{Measurement} x100\% \quad (6)$$

Set The Image Scale

$$S = \frac{Camera\ Focal\ Length}{High\ flying\ drone - Object\ Height} = \frac{f}{H-h} \quad (7)$$

IV. Results and Analysis

The first thing to do is to determine the initial height and initial path for reference as shown in fig 5. After that the results from before and after will be compared. The path that has been obtained from the initial data, will be merged from the first and second lines, the results of the merger will form a graph to find the optical path in the image in the air.

The initial data collection is done 30 times from 3 different heights. Determining the initial path is based on the focal point of the lens on the drone and the power consumption that is taken.

The results of the initial data obtained 3 different images, the image is displayed as shown in the Fig. 5, where a height of 100m has an error assumed to be 6%, 80m has an assumption of error 9%. The error in this study is a blank spot, this occurs due to the limitations of the camera drone that cannot cover the intended area.

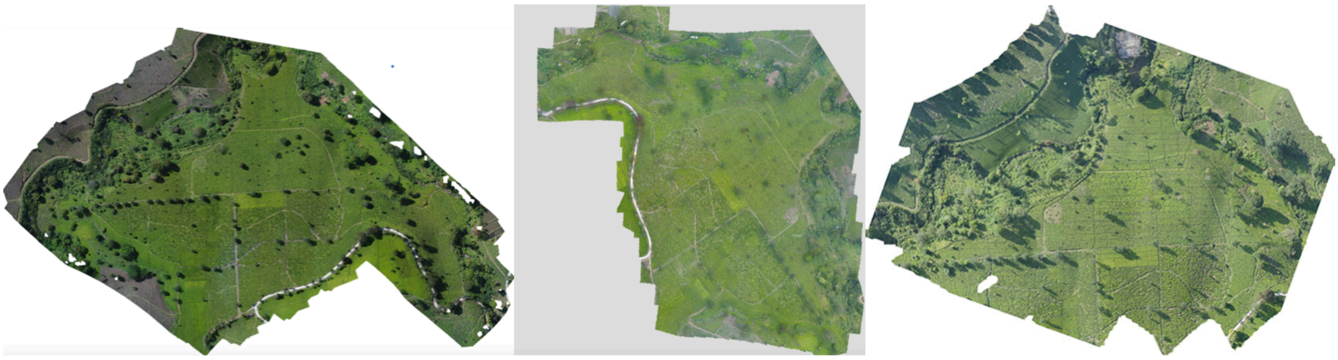

Fig. 5. Initial Map

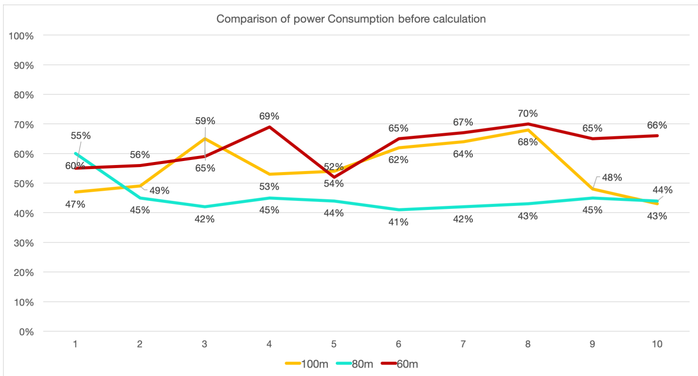

Fig. 6. Power Consumption Initial Data

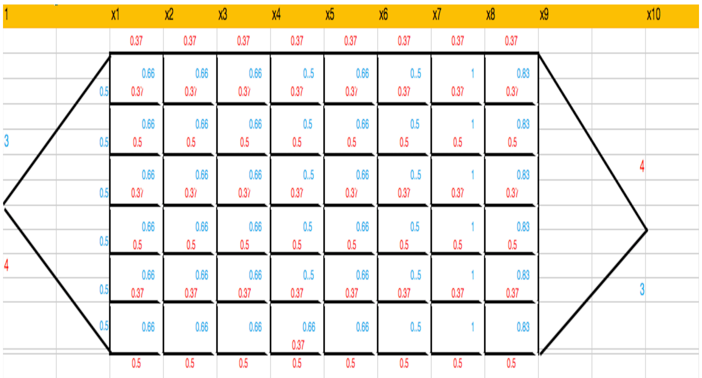

Fig. 7. The Result of the merger 100m

In addition to the picture, the power consumption for each height is also obtained From each height a number of different power consumption is obtained, the height of 100m has an average power consumption of 55% or 49Wh, the height of 80m has an average power consumption of 45.1% or 40W, and 60m has an average power consumption of 62% or 55Wh. This power consumption in Fig.6. is useful to be a reference in determining the optimum shooting path. The next step is to find the optimum path for shooting by using dynamic programming and kruskal algorithm, with the calculated parameter is the power consumption that has been obtained

A. *Calculation*

- 100m

The results of combining two lines in Fig. 7. shows 10 new paths x1, ... x10, which has different values. 10 lines of paths will be searched to find a new path. Calculations using dynamic programming starting from x10 will result from later calculations in the form of a new path. The path that is generated may not form the cycle cycle or looping, because both of these errors will cause the image produced on the map to become damaged, besides the two errors resulting in the consumption of the UAV becoming more wasteful than before.

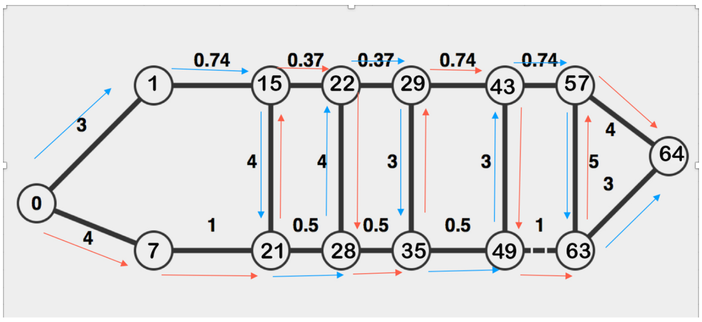

Fig. 8. New Path 100m

The results combine two lines in Fig. 7. shows 10 new paths x_1, ...x_{10}, which has different values. 10 of these lines will be searched to find a new path.

In table. 1. it can be seen that the blue line has a power consumption value of 28% less than the red 31%. So the blue line saves more energy than red in shooting in the air. The next step is Testing again in the tea plantation to see the power efficient.

TABLE I

KRUKSAL RESULT 100M

First Line	Second Line
3	4
0.74	1
4	4
0.5	0.37
4	4
0.37	0.5
3	3
0.5	0.74
3	3
0.74	1
5	5
3	4
28% \ 24.8 Wh	31%\ 27.6 Wh

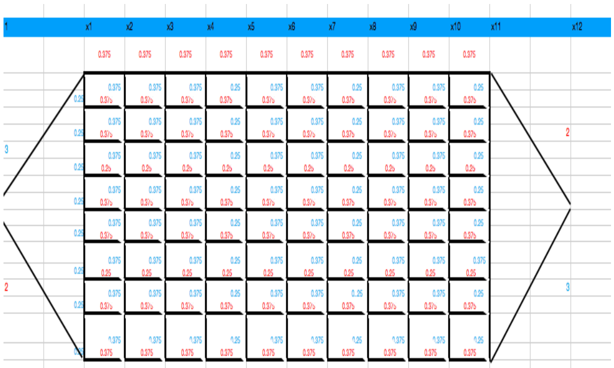

Fig. 9. The Results of the merger 80m

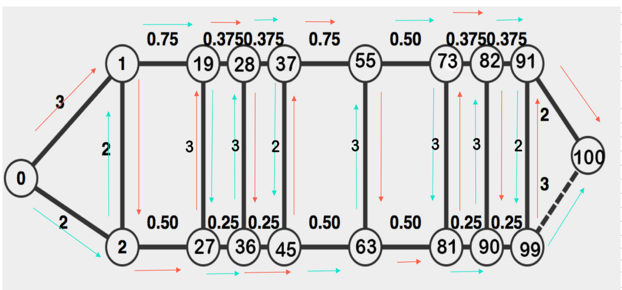

Fig. 10. New Path 80m

- 80m

The results combine two lines in Fig. 9. shows 12 new paths x_1, ...x_{12}, which has different values. 10 of these lines will be searched to find a new path.

Calculations using Dynamic programing are done by going back from x_{12}, .. x_1, to find out the possibility of a new path. After the calculation is done, get the results in the form of a new shooting path as shown in fig.10.

TABLE II

KRUKSAL RESULT 80M

First Line	Second Line
2	3
2	2
0.75	0.5
3	3
0.25	0.375
3	3
0.375	0.25
2	2
0.5	0.75
3	3
0.5	0.5
3	3
0.25	0.375
3	3
0.375	0.25
29%\25.8 Wh	29%\ 25.8 Wh

Calculations using Dynamic programing are done by going back from x_{12}, ..x_1, to find out the possibility of a new path. After the calculation is done, get the results in the form of a new shooting path as shown in fig.10.

The results of calculations using the Dynamic Programming algorithm, obtained a new path with each waypoint solution between the paths x1, .. x12 as in table 2. The path will be recalculated using the Kruskal algorithm to find out the power efficient.

In table 2. it can be seen that the blue line has a power consumption value of 29% and red 29%. Both lines have the same value, so the two pathways are more optimum when compared to the height of 100m. The next step is Testing again in the tea plantation to see its performance and compare the results between the initial data and the final data.

B. Result and Comparison Data

TABLE III

COMPARISON DATA 100M

Name	100m			
	Before		After	
Total Image	185		103	
Asumption Error Image	6%		4%	
Power	55%	49Wh	29%	49Wh
Max Power	68%	60Wh	68%	60Wh
Min Power	43%	38Wh	27%	24Wh

TABLE IV

COMPARISON DATA 80M

Name	80m			
	Before		After	
Total Image	198		124	
Asumption Error Image	4%		3%	
Power	45%	40Wh	28%	24Wh
Max Power	60%	53Wh	33%	29Wh
Min Power	42%	37Wh	27%	24Wh

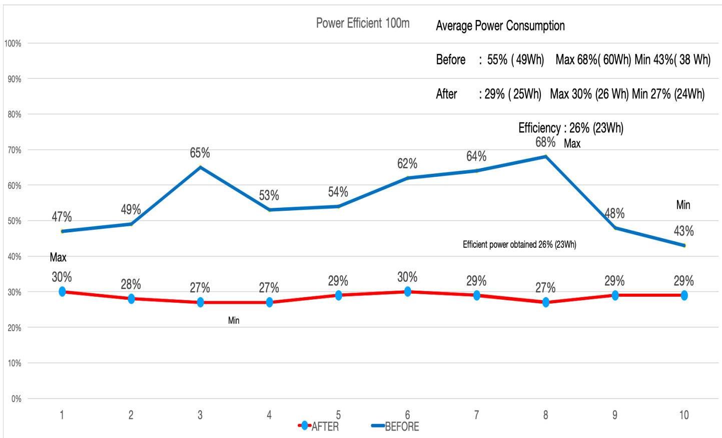

Fig. 11. Efficiency Power for 100m

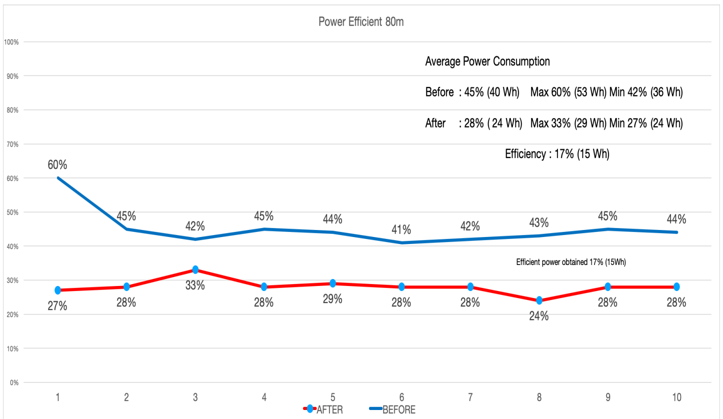

Fig. 12. Efficiency Power for 80m

From tables 3 and 4 we can see the difference after implementing the two algorithms. That the change in track taken has an impact on more efficient power consumption than before, besides that the number of photos obtained is less compared to the previous one but the results of the maps produced have not changed from before and can still be received.

The calculation results using dynamic programming and kruskal, have an impact on power consumption that is better than before show in Fig.11 and 12 The height of 100m is obtained by an average power consumption of 29% or 25 Wh each iteration, this figure is more efficient 26% or 23 Wh than the data before calculation, which is 55% or 49Wh.The results at an altitude of 80m obtained the results of an average power of 28% or 24 Wh each iteration, this number is more efficient 17% or 15 Wh of the data before the calculation of 45% or 40 Wh. by using these two algorithms the energy produced will be better.

V. CONLUSION

The result of implementing dynamic programming algorithms and kruskal is to get an optimum path that is suitable for monitoring tea plantations, especially in Indonesia Tea and Chinchona Research Insitute (Pusat Penelitian Teh dan Kina, PPTK). From the results obtained, it can be concluded that the appropriate height to monitor the tea plantation land is 80m height, because this height has the assumption of an initial image error of 4% and after calculating 3% thiss result is smaller compared to other heights, besides getting pictures which is good at getting more efficient power, in the initial data 28.1% or 25 Wh is more efficient and saves 17% or 15Wh after comparing the previous data which has an average power value of 45.1% or 40Wh each iteration. The height of 80m is highly recommended to monitor the tea plantation because the results of image accuracy are 90% and the required power is small.

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