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Research paper

Assessment of Images of Birds Captured by Low-Cost Drone using Agisoft Photoscan

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Abstract

Birds are significant flying vertebrates in agriculture, thus the search for effective bird detection technique has been getting increasingly necessary. This paper proposes a low-cost technique to detect birds using off-the-shelf drone with built-in camera. The objective of this research is to identify the number of birds at the selected area based on images captured by drone at different altitude. The images were analysed using Agisoft Photoscan software. The research was carried out at Tasik Shah Alam, and focused on storks. The results indicated that the most number of storks detected were at 15 and 20 metres. This signifies that the closer the camera is to the birds, the clearer the images will be. At lower altitude, the images captured are found to be more precise than at higher altitude. This is probably due to the vegetation blocking the view of the camera at higher altitude. It is recommended to use thermal camera compared to visual camera due to the former capability of detecting hidden birds based on heat generated, where visual camera could not capture.

Keywords: *Agisoft Photoscan, Unmanned Aerial Vehicle (UAV), Drone, Image Detection*

1. Introduction

Birds play a crucial indicator of the overall environmental health. With its limitless number of birds surrounding the environment and human population, there are bound to be issues. Birds usually gather in huge number on rooftops and agriculture area like a farm. Thus, farmers are one of the unfortunate victims of bird infestation. Some birds will hunt aggressively and freely consume crops before they can be harvested. It is very detrimental to farmer due to these attacks by birds, as it can result in enormous financial crisis. There are a lot of issues regarding birds like fouling, spreading diseases and creating physical damage. Fouling is unsightly droppings that can build up in roosting sites, foul paved areas nearby as well as cause slip and fall risk for staff in businesses and members of the public in urban areas. Bird droppings can contain many types of bacteria, viruses, and parasites which can contaminate food, surfaces and goods. The pathogens in the bird droppings include Salmonella, E. coli, and Histoplasma [1], which can then infect people handling the goods and eating contaminated food. The most damage cost can also be due to bird strike.

Conflicts between birds and aircraft have increased dramatically in the recent years because the world has become a global village through technological advancement in communication and significant improvement in aircraft design [2]. The occurrence of wildlife-aircraft collisions especially involving birds is rising [3]. In addition to the economic losses, some collisions have resulted in the loss of human life. Although the economic costs of bird strikes are extreme, the cost in human lives lost when aircraft crash as a result of strikes best illustrates the need for management of the wildlife strike problem [2]. Hence, the ability to detect birds in images has very important applications in video surveillance, content-based image retrieval, and aviation safety. However, detecting flock of birds is a difficult task due to their small size and variations in background.

Several methods are already being implemented in aerodrome to protect aircraft from any unexpected accident with birds. However, the unwillingness of airport management to invest more to resolve this problem caused by the low level of understanding of the true costs for airlines in terms of direct damages, delays, and cancellations [4] is the reason different type of safety measures are applied at different levels from airport to airport. It is recently being considered that further protections should be provided, so that, safer flights can be accomplished. It is of huge importance around airports to be alert of the state of flocks because the height of planes is low, and the severity of a strike could be catastrophic. Indeed, low heights are the zones with greater avian activity [5].

Following the latest trend of Industry Revolution 4.0, this research would propose a new concept to use a low-cost technique to detect birds using drone, DJI Phantom 3 with built-in camera to identify the flock of birds at ground level or tree level at a particular area using drone with camera; and capture its images at low altitude for the sole purpose of creating a mapping or orthomosaic image; for further analysis the data to reduce the chance of bird strike and keep the aircraft and the people safe. It also can help the farmers to minimise the crop's damage done by birds through detecting the nearby area for any bird infection.

2. Literature Review

2.1. Bird Monitoring Methods

There are various methods available for bird monitoring such as direct observation [6], active infrared camera [7], passive infrared camera[8], capture-recapture technique [9], radio tracking or telemetry [10], satellite-based remote sensing [11] and radar-based monitoring technology [12]. Radar-based methods have been used in bird migration studies for more than 60 years [12] and are able to detect birds over a long range, day and night. A radar-based method provides information about bird moving direction and speed, migration intensity and, depending on the type of radar, also flight altitude and wing-beat patterns [13].

Vision-based approaches using camera systems have existed since the 1950s. Cameras have also been deployed by biologists to observe feeding behaviour and population parameters of animals. Commercial remote camera systems have been widely used in wildlife observation including birds [14].

Satellite-based remote sensing images are extensively used in terrestrial studies on environment dynamics for mapping and monitoring land use changes, animal behaviour, and invasive species. Remote sensing technology has proved to be highly effective in acquiring data for coastal environmental monitoring and management.

Cameras with active infrared (AIR) sensors have triggers that consist of two pieces of equipment: an IR (infrared) transmitter that emits an IR beam, and an IR receiver that detects an IR beam. The detection zone (the area the animal must enter to activate the camera) is a straight line, which can span up to 45 meters [7], between the transmitter and the receiver. The system will only activate and capture an image after an object enters the detection zone, thus breaking the IR beam for a specified period of time.

Cameras with passive infrared (PIR) sensors represent a majority of the remote camera market and have triggers that consist of one piece of equipment that detects both heat and motion. Motion is required, as the system is activated by a rapid change in the amount of heat detected in the detection area. Some systems have a long-wide detection zone that covers the entire photo area; others cover only a short-narrow strip in the middle of the photo area as well as everything in between.

The direct approach means that approaching the birds with a spotting scope or binoculars and observes the birds sitting on their nest or resting on a tree. Some binoculars are equipped with a laser distance sensor. On approach the bird flies away. Therefore, carefully and quietly avoid any tree or other obstacle and appear directly behind the bird and keep an eye on it while approaching. This is the most traditional method used to detect bird.

Recently, UAVs have been rising in popularity due to its immense potential capability in surveying difficult-to-reach place. By mounting cameras and additional sensing equipment on these aerial systems, photos and videos can be captured while exploring a place that seems impossible for humans to reach on foot. This data can be recorded, geolocated, and mapped for further inspection by experts so that appropriate precautions can be taken to allow land management practices to proceed. In addition, it can also conduct a real-time visual inspection of captured video and infrared data allowing researchers to further investigate potential sites of interest and gather additional information about nesting areas.

3. Methodology

3.1. Selection of Test Site

The Shah Alam Lake Garden (refer Figure 1) was selected as the test site for this research, because it has an island full of birds like storks, geese, and crows. It is also has a quite a distance from the public. Thus, it is safe for the drone to fly to the bird's area. For a few days of surveying at site location, it is found that there are a lot of storks on top of the tree at the bird's island. Therefore, the painted stork was chosen to be observed as shown in Figure 2. They hunt in flocks in shallow waters along rivers or lakes. Usually nest colonially in trees. This large stork has a heavy yellow beak with a down-curved tip. Painted storks feed in groups in shallow wetlands, crop fields, and irrigation canals. After they are fed they may stand still on the shore for long durations [15]. For a stork, it is medium-sized, standing about 93–102 cm tall, 150–160 cm in wingspan.[16]

Fig 1: Shah Alam Lake Garden

Fig 2: Painted Stork

This bird was chosen due to its distinguishing feature which was its white colour body especially its large size where it can be easily recognized from afar or on top of a tree. The colour and its size make it hard for it's to blend into the surrounding trees. Thus, it can be easily observed or detected as the camera only used to capture images for observation purposes.

3.2. Image-Capturing Method

The flight test was conducted at Tasik Shah Alam near an island of birds that consists of stork, crow, and goose. Upon arrival, an ideal location was chosen to fly the drone where fewer trees are nearby but away from the public. This takes account for take-off, landing, and any emergency procedures necessary. It also needs to be within visual line of sight of the drone. Next, the drone preparation was carried out to ensure the drone was able to fly; which included installing the 4 blades, the battery and remove any safety protection on the camera. The drone flight test was conducted autonomously using a smartphone application called Precision Flight. During each flight, the drone will autonomously fly at the site location via flight path set on the Precision Flight before flight take-off to capture images of storks.

3.2.1. Precision Flight Application Software

There are several steps needed when using application Precision Flight [17]. The first steps are all other applications were closed out before running the Precision Flight application. The application will not work if there are any similar applications still running in the background. Next, "Create Flight Plan" was selected followed by "Grid" survey type that was selected. This will program a lawnmower path with given overlap values to get full coverage on the area. The flight name was selected with its designated altitude for each flight.

This paper focuses more on low altitude which is 15m, 20m, 25m, 30m, and 35m for better resolution of stork's image. The most important part of Precision Flight was choosing the area to be

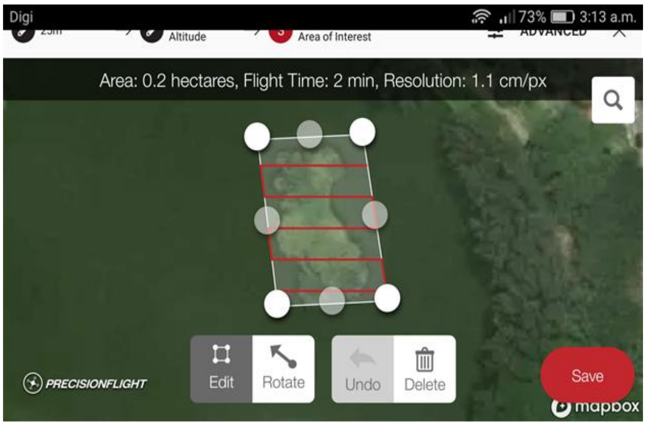

Fig. 3: The area that will be cover by drone (white square) with the flight path (red line)

flown on the screen as shown in Figure 3. The area on the screen can be rotated in any direction. The overlap setting was set to 70% for both front and side. The speed of the drone was set to 10m/s for every flight. This was made to make sure the speed does not influence the image as the main concern for this paper is the drone's height.

Once the flight plan was completed, the mission can be saved. Once chosen to fly the mission, the drone will take-off directly towards the sky until it reaches the designated plan altitude. Once at plan altitude, it will head out to the first waypoint of the survey. The first waypoint of a survey was actually programmed based on the exit point of the drone at the end of the survey. The final waypoint was always the closest exit point for the drone when the battery is running low. Therefore, the starting waypoint is typically one of the furthest waypoints in the flight plan.

Once completed, it will return to the home position at survey altitude and begin its descent for landing. Low battery warnings will be signalled with around 30% battery left. This will trigger the drone to return home and land immediately. During all segments of flight, necessary emergency procedures were followed if the drone begins acting strangely or flies off the planned course of flight. Throughout the flight, the drone was within visual line of sight in case of an emergency. At the end of the flight, the drone was landed safely, and the propellers were waited until it stopped spinning before approaching the drone. After powered off the drone, the images captured were ready for image post-processing process.

3.3. Post-Processing Technique

Post-processing process is a process that transforms images captured by a camera either to be closer to what the eyes saw or to alter the image artistically. This section consists of step-by-step process on how to form a mapping from the hundreds of images captured. The software that was used is Agisoft Photoscan. It is also one of the most widely used and user-friendly software available in the market. Thus, this application was used in this project to evaluate the mapping of birds from the images captured.

Ground Sampling Distance (GSD) is the distance between two consecutive pixel centers measured on the ground. It is the most important parameter that determines the scale and accuracy of the production of Orthophotos [18]. The GSD value of each image has been captured at different altitude as shown in Table 1.

Table 1: The ground sampling distance (GSD) value of each image at different altitude

Height (m)	Ground Sampling Distance (GSD)
15	0.65 cm/px
20	0.86 cm/px
25	1.08 cm/px
30	1.30 cm/px
35	1.51 cm/px

3.3.1. Agisoft Photoscan Software

Agisoft PhotoScan allows generating georeferenced dense point clouds, textured polygonal models, digital elevation models and orthomosaics from a set of overlapping images with the corresponding referencing information [18]. This section describes the main processing steps of DEM/Orthomosaic generation work-flow for a set of images without ground control points, which are also at a different time will result in different position of birds unless the birds are stationary during the whole process. Next, the chosen photos will be aligned together for the stitching process. At this stage, PhotoScan finds matching points between overlapping images, estimates camera position for each photo and builds sparse point cloud model. The accuracy of this project was all set to high for a better-quality mapping with other settings was set to default. The time for it to process depends on the number of images added and their resolution where sparse point cloud model will be shown in the Model view. Camera positions and orientations are indicated by blue rectangles as shown in Figure 4.

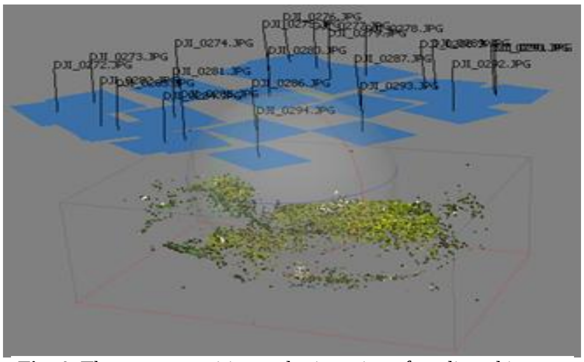

Fig. 4: The camera position and orientation after aligned images

Then, the dense point cloud was built. This is the most computation-ally intense portion of the Photoscan workflow as it takes the longest times for it to finish compared to other processes. Based on the estimated camera positions, the program calculated the depth information for each camera to be combined into a single dense point cloud. The quality of this process was selected at high. There are other processes like meshing and texturing where it can be skipped if the polygonal model is not required as a final result. After that, Digital Elevation Model (DEM) was built as shown in Figure 5. A digital elevation model is a bare-earth raster grid referenced to a vertical datum. When filter out non-ground points, a smooth digital elevation model is produced. DEM can be created either by dense cloud or mesh model, but the first option gives a more accurate result which this paper had followed.

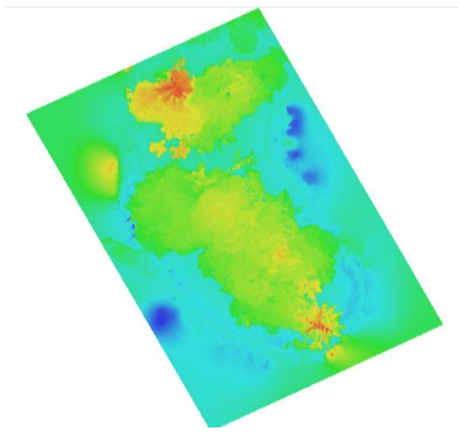

Fig. 5: The Digital Elevation Model (DEM) view of the test area

Building orthomosaic or mapping was the last step required to finish this Agisoft software. An orthophotomosaic is a raster image made by merging orthophotos; aerial or satellite photographs which have been transformed to correct for perspective so that they appear to have been taken from vertically above at an infinite distance [19]. Google Earth images are of this type. A digital elevation model (DEM) was needed to create a precise orthophoto as distortions in the image due to the varying distance between the camera/sensor and different points on the ground need to be corrected. After the orthomosaic had been produced, it has already to be analysed.

4. Results and Discussions

4.1. Mapping of Storks at Different Altitudes

Fifteen flight tests were carried out on three different days in the same area. The first day of flight test was conducted on 23rd April 2018 on Monday morning at 9 am. The altitude for this project is aiming at low altitude which is between 15m to 35m, assuming the image of birds cannot be seen clearly at high altitude. The flight was conducted at the highest altitude first, which is 35m, to the lowest altitude of 15m. This was done to avoid alarming the stork early during the image-capturing process. If starting at the lowest height, it may cause the stork to be alarmed, scared and flew away. This may lead to a reduction of storks on the tree. At the worst case, the storks may collide with the drone causing the drone to fall into the water.

Five test flights was conducted on the first day from a height of 35m and decrease by 5m for the next consecutive flight (30m, 25m, 20m, and 15m). Table 2 shows the important information for each drone's flight for every flight test. It shows the flight name, date and local time of the UAV take-off for each flight. Moreover, it shows the number of storks detected from the mapping, the height flown and the weather at the time of flight. Every stork detected was manually counted to confirm the images detected. A strong wind can really affect the mapping quality as the drone may be tilted during the image-capturing process. Thus, producing low-quality mapping.

At certain occasions during the flight tests, there were birds like crows and storks keep following the drone when it was capturing images. It normally happened at lower altitude which was at the height of 15m and 20m. This is when the drone is the closer to the birds. Based on direct observation, the birds must have felt curious about an unknown thing disturbing their home. Although, this action may seem harmless, but the slightest mistake may result in a collision between the UAVs and the birds which will bring harm to both parties.

From the Table 2, the stork detected at height 15m was not recorded. This is due to images failed to stitch together. What is produced from the Agisoft was a broken map that only contains part of the image as shown in Appendices. Images taken at low altitude of 15m cannot be used for mapping. The unobstructed storks were manually counted to determine the population of stork from the mapping at different days and height.

According to Table 3, the highest drone's flight duration was below 5 minutes. This implies that the stork's images can be captured less than 5 minutes compared to another method where it might take hours or even days. The average storks detected for flight Day1, Day 2 and Day 3 are 26.5, 25, and 32.75 respectively. This indicates that the mapping shows that for the first day only 27 storks were visible to be seen and be counted form the mapping. Follow by the second day with 25 storks and third day with 33 storks

Table 2: The number of storks detected from mapping

Flight	Date	Time	Height(m)	Stork detected from Agisoft	Weather
Day 1a	23/4/2018	9:11	35	20	Cloudy
Day 1b	23/4/2018	9:16	30	27	Cloudy
Day 1c	23/4/2018	9:37	25	28	Cloudy
Day 1d	23/4/2018	10:09	20	31	Cloudy
Day 1e	23/4/2018	10:22	15	-	Cloudy
Day 2a	28/4/2018	9:37	35	23	Sunny
Day 2b	28/4/2018	9:42	30	25	Cloudy
Day 2c	28/4/2018	9:46	25	25	Sunny
Day 2d	28/4/2018	9:56	20	27	Sunny
Day 2e	28/4/2018	10:14	15	-	Sunny
Day 3a	5/5/2018	11:09	35	30	Sunny
Day 3b	5/5/2018	11:13	30	33	Sunny
Day 3c	5/5/2018	11:19	25	32	Sunny
Day 3d	5/5/2018	11:23	20	36	Sunny
Day 3e	5/5/2018	11:31	15	-	Cloudy

Table 3: The flight path information for each flight

Flight	Area (hectares)	Duration	Height(m)	Speed (m/s)	Images captured
Day 1a	0.2	2:33	35	10	23
Day 1b	0.2	3:03	30	10	26
Day 1c	0.2	3:15	25	10	27
Day 1d	0.2	3:20	20	10	46
Day 1e	0.2	4:07	15	10	52
Day 2a	0.2	2:33	35	10	21
Day 2b	0.2	2:53	30	10	26
Day 2c	0.2	2:58	25	10	27
Day 2d	0.2	3:47	20	10	47
Day 2e	0.2	4:07	15	10	51
Day 3a	0.2	2:33	35	10	22
Day 3b	0.2	3:02	30	10	28
Day 3c	0.2	3:21	25	10	35
Day 3d	0.2	3:50	20	10	47
Day 3e	0.2	4:39	15	10	60

Table 3 shows that the area covered by the UAVs was 0.2 hectares for every flight. However, the actual covered area was more than that, but the Precision Flight only shows the value of the area in one decimal place. Thus, the reading of the area cannot be estimated accurately. This depends on the size of the area as the higher the drone flew, the larger the size of the area needed to be covered.

The speed of the drone was set at 10 m/s for each flight. The focus in this project was more towards the difference in height the drone captured the images, not its speed. Even though the speed might affect the image quality, the height also plays an important aspect during image capturing process.

This method is better compared to another method especially directly approach the stork which is energy and time-consuming. This is what a drone can accomplish if used correctly and effectively.

4.1.1. Stitching Failure

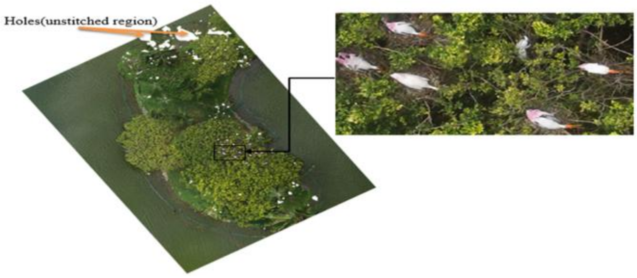

Fig. 6: Orthomosaic image (left) with a close-up image of storks (right)

Beside storks, trees, and lake, this orthomosaic images can be seen to contain full of 'holes' (unstitched regions) as shown in Figure 6.

Some unstitched region obstructed the view of some storks which may affect the counting of storks. In Figure 6, it shows the difference between these holes and the storks with a close-up view of the storks. There is no such thing as these unstitched regions exist in the images captured. Apparently, the stitching failure is appeared during the image post-processing process. There are a few possible reasons why this stitching failure existed [17].

The first and most important reason is that the image overlapping was insufficient causing the mapping cannot be properly reconstructed [17]. The more images overlapping with each other, the better the quality of the mapping produced. To produce more overlapping images, more images need to be captured at a different height or flight path of the drone. However, in this research, the problem cannot be solved just by adding the image taken from different altitude. The painted stork may stay static at their current position or move around at a short distance or fly away. The possibility of the stork to fly away is high when the drone needs to fly for a second time. One way to overcome this problem is to increase the overlap image of the front lap and side lap from the current 70% to 80%. Flying with more overlap is the easiest way to get more matched features in the imagery, but it does come at the expense of reducing the area the drone can cover in one flight. It is better if the flight plan can create a cross-hatched flight plan for more thorough coverage [17]. The increase in images from different angles, the better the quality or resolution of the mapping produced.

Next, image quality was insufficient which caused the stitching failure to happen [17]. Since this project is using a low-cost drone which uses a camera of 12 megapixels, the image quality should be good if it only involves the images, but not stitching process. The low-quality camera may sometimes become unfocused and cause the image's quality to be reduced. The better the quality of images captured, the more accurate the stitching process can produce the mapping.

The reduction in quality of images also due to lack of light during image capturing process [17]. Repeating the flight test during clear day can overcome this issue. In addition, the low quality camera of Phantom 3 can also affect the image's quality caused by vibration during flight [17] . Blurred images may cause by either the camera shutter speed is not fast enough, or the drone is flying too fast. The best way to solve this is to improve shutter speed but flying slower or at higher altitude will help to reduce this matter.

Non-nadir photos can also affect the stitching failure [17]. Images were taken by a camera pointing to the nadir direction. Pointing to the nadir means that the camera axis (in the direction of the lens) is perpendicular to the ground or object. By including the horizon, the internal distance of the map will be distorted. Agisoft Photoscan will try to include the far away images in stitching rather than the area of interest below.

The test site is also one of the reasons for stitching failure as it was a homogenous imagery [17]. A great example of homogenous imagery is a field with full crop cover. Short distance image of the tree may also become a homogenous imagery. Because there is a little variation or distinguishable features, and a tendency to have hard-to-determine patterns, it can be difficult to stitch together the images. Together with taking photos at a low altitude lowers the surface area per image, which will make the images difficult to stitch together. This can result in blurred mapping. It is difficult to capture the object on ground in one flight test, especially at lower altitude. Therefore, it is better to fly at higher altitude in order to capture at a wider angle.

4.1.2. Verification of Images Captured

Due to stitching failure that exist; the comparison must be done to determine the total number of storks available in the area especially on top of a tree. Since the map was produced due to the hundreds of images stitched together, thus it is obvious to determine the authenticity of the population of stork by manually counting the number of storks from the images captured. Observing from only one image is not accurate because the images captured does not cover the entire area. Hence, more images need to be observed that cover the whole area to determine the number of storks present. Table 4 shows the comparison between the images, the mapping and its differences. It shows that the storks detected from the image captured is higher compare to orthophoto produced from Agisoft Photoscan. This is due to the existing holes in the mapping which affect the stork's count where the counting cannot be done accurately and precisely.

Table 4: Comparison of storks detected between images captured by the drone camera and mapping images from Agisoft PhotoScan

Flight Id	Height (m)	No. of stork detected		
		Image captured from camera	Mapping produced from Agisoft	Differences
Day 1a	35	40	20	20
Day 1b	30	40	27	13
Day 1c	25	39	28	11
Day 1d	20	40	31	9
Day 1e	15	40	-	40
Day 2a	35	34	23	11
Day 2b	30	34	25	9
Day 2c	25	35	25	10
Day 2d	20	40	27	13
Day 2e	15	40	-	40
Day 3a	35	49	30	19
Day 3b	30	50	33	17
Day 3c	25	50	32	18
Day 3d	20	56	36	20
Day 3e	15	57	-	57

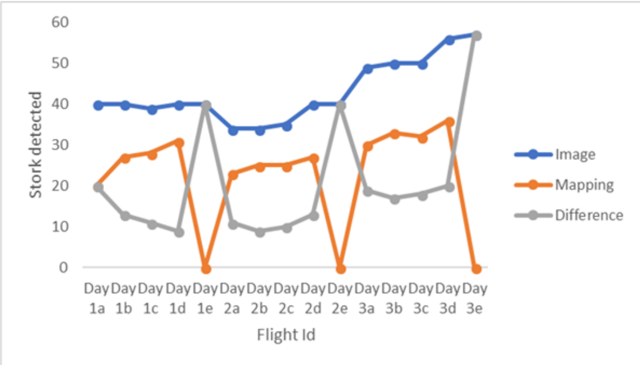

Fig 7: Flight Test vs Number of Storks Detected

The graph shown in Figure 7 illustrates the difference between number of storks from camera images and mapping. The number of storks counted from the captured images by the camera is more reliable compared to the number of storks images process in AgiSoft software. There is no image of storks detected obtained from the mapping using AgiSoft on Day 1e, 2e and 3e. This is because the mapping produced by Agisoft for these days show blank white spots and also only partial image shown.

5. Conclusion

Drones can be used to capture image from aerial view for better coverage. In this research, DJI Phantom 3 was chosen due to its low-cost, flight duration and camera quality. The storks images had been captured and mappings were produced by Agisoft where the stork can be visibly seen and be counted. However, a good mapping cannot be shown due to the existence of unstitched region. The possible reasons of unstitched region occurred are cause by low-quality images, less overlapping images, and homogenous imagery. It can be concluded that at lower altitude, the images captured are more accurate than at higher altitude. This is probably due to some vegetation blocking the view of the camera at higher altitude. Based on the result obtained, the mapping can be produced at the height of 20m, 25m, 30m, and 35m. Even though it does not indicate accurate result, but it has proven that the number of storks can be detected from the mapping at different altitudes.

It is recommended to fly at a higher altitude and increase the overlapping images to increase the mapping quality. The specifications of the UAV also play an important role, as the low-cost drone will give low-quality result whereas high-cost drone will produce a higher quality result as the specification in terms of camera quality and flight performance is better compared to the low-cost ones. Besides mapping, a thermal camera can be used to detect birds more accurately [20]. Thermal camera can detect body heat generated by living creature even though they are hiding under a bush, or not visible physically. However, the thermal camera is more expensive compared to a camera, and to conduct this research using thermal camera may be costly for research without funding.

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