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Research paper

Evaluation of Low Cost Digital Cameras for Producing Photogrammetric Output from UAV

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Abstract

Recently there a lot of improvement in digital photogrammetry and this allow photogrammetry to become faster and cheaper . This study discuss about two type of low cost camera which is the compact camera (Canon Power Shot SX230) and action camera (Xiaomi yi) where both of them have different lens distortion. This study is conducted within UTM (Universiti Teknologi Malaysia) Skudai campus at Kolej Tun Razak. Both of the Canon Power Shot SX230 and Xiaomi yi camera would be attach to the UAV to take aerial photo with three different altitude which is 60 meter, 80 meter and 100 meter with a similar flight path. Check point (CPs) and Ground control point (GCPs) were also established using rapid static technique of Global Positioning System (GPS) and Total Station. The Canon Power Shot SX230 and Xiaomi yi camera is then calibrated using checkboard calibration this is done by using Agisoft Lens software. Then all of the pictures that been taken by the Canon Power Shot SX230 and the Xiaomi yi would be processed by using Agisoft Photoscan software to generate Digital Elevation Model (DEM), orthophoto and contour line. The accuracy of DEM was determined based on Root Mean Squared Error (RMSE) value. Both of the result is then analyze visually and statically. Overall both of the camera gives a slight different in accuracy.

Keywords: *Photogrammetry; UAV; Lens*

1. Introduction

Photogrammetry is a measurement from multiple image to compute the coordinate in three dimensional. There two type photogrammetry and that is aerial photogrammetry and terrestrial photogrammetry (**1**). For aerial photogrammetry usually been collected using metric camera. However its very costly and need to be plane carefully (**2**). Thus the use of digital camera on the UAV for topographic map, orthophoto and other photogrammetry product are much more cost effectively (**3**).

In recent year a lot of development on UAV have been improved. UAV is an aircraft that does not required a pilot and fly automatically using auto pilot (4). Originally UAV is used by the military for recognition, environmental observation, maritime surveillance and mine removal activities. Eventually UAV is used for public uses like environmental surveillance, spraying, infrastructure maintenance and remote sensing application like photogrammetry (5). Unlike any other aircraft most UAV like the multirotor use battery this resultant a shorter flight time thus smaller coverage for aerial mapping (6).

Action camera like Xiaomi yi is smaller and lighter compare Canon Powershot XS230HS thus mush more suitable to use for UAV application. With this small camera size it reduces the cost to build the UAV and can longer flight time. With longer flight time it can cover a wider area, and thus the cost of producing a map is that relatively cheap. One of the issues using action camera like Xiaomi Yi is the lens. It use fish eye lens that cause the barrel distortion. Because of these it never been widely used for aerial mapping. This research provide the evidence that by using lens calibration even the distorted image can be used to produce photogrammetry output which is orthophoto, contour line and Digital Elevation Model (DEM). The benefit of this research is that the UAV can use Xiaomi Yi which a lighter weight compare to Canon Powershot XS230HS to extend the flight time thus increasing the coverage of the map.

2. Lens Distortion

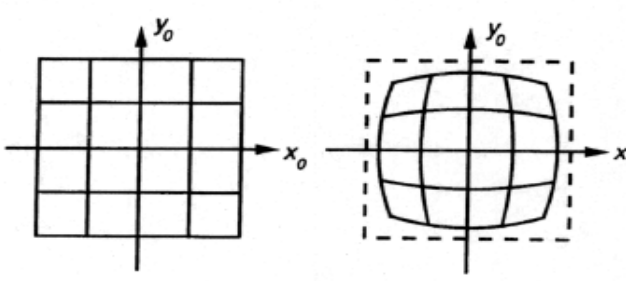
The distortion, often also called (optical) distortion, is a geometric imaging error of optical systems which leads to a local change in the imaging scale. The scale change is based on a change in the magnification with an increasing distance of the image point from the optical axis. The distortion is therefore rotationally symmetrical about a point, which is also called distortion center. The cause of the distortion lies in diaphragms that narrow the beam of the image in front of or behind the main plane of an optical system with an opening error.

If the magnification increases to the edges of the image field, then a square is recorded as a pillow. In the opposite case we speak of barrel-shaped distortion. Higher-order distortions may also occur, and the superposition of different orders may lead to a wavy image of straight lines ("wavy distortion").

In optical devices for everyday use, distortion is not a significant disadvantage and is therefore accepted. Thus, spectacles for myopic sightedness have a strongly barrel-shaped distortion toward the edge. In the case of devices with several lenses, such as telescopes , the distortion can be kept low by optical compensation. These distortion-free optics are called orthoscopic lens systems. However, in the case of visually used optics, a pillow-shaped distortion is not infrequently implemented in order to eliminate the disturbing globular effect.

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If photographic images are used for precise measurements, lens systems that are corrected as far as possible, such as telecentric lenses, are required . In addition, the remaining distortion is determined by measurement technology and corrected by the analysis of the image.



Without Distortion Barrel Distortion

Fig. 1: the difference image distortion and no distortion

In barrel distortion, increasing the image decreases with increasing distance from the optical axis . The visual effect is as if the image is put around a sphere (or barrel). Lenses Fisheye , having a hemispherical field of view, using this type of distortion as a way to display infinitely wide plane of the object in a finite area of the image. In the zoom lens barrel Distort appears in the center of the lens focal length range becomes greater in the wide angle range

The lens distortion can be corrected using a mathematical model calibration Brown was used to determine the appropriate semuaparameter decisive change in shape of the lens on the image (7). Models who are using the coefficients of the polynomial of odd and even also for radial and tangential lens distortion. The equation for the Brown model is divided into four, two for radial and two tangential.

$$dx_{radial} = x*(1+k_1*r^2+k_2*r^4+ k_3*r^5)$$
$$dy_{radial} = y*(1+k_1*r^2+k_2*r^4+ k_3*r^5)$$
$$dx_{tan} = x+1(2*p_1*x*y+p_2*(r^2+2*x^2))$$
$$dy_{tan} = y+1(p_1*(r^2+2*x^2)+2*p_2*x*y))$$

where

$$r=\sqrt{x^2+y^2}$$

x and y = actual position

dx and dy=position on the distorted image

$k1$,$k2$ and $k3$= constant for radial distortion

$p1$ and $p2$= constant for tangential distortion

3. Methodology/Materials

For this study, it been divide by three phase which data acquisition, camera calibration and processing and analyzing. This study is conducted within UTM (Universiti Teknologi Malaysia) Skudai campus at Kolej Tun Razak. Both of the Canon Power Shot SX230 and Xiaomi yi camera would be attach to the UAV to take aerial photo with three different altitude which is 60 meter, 80 meter and 100 meter with a similar flight path. Ground control point (GCPs) and check point (CPs) were also established using rapis static technique of Global Positioning System (GPS) and Total Station. Figure 1 show the flowchart of the study

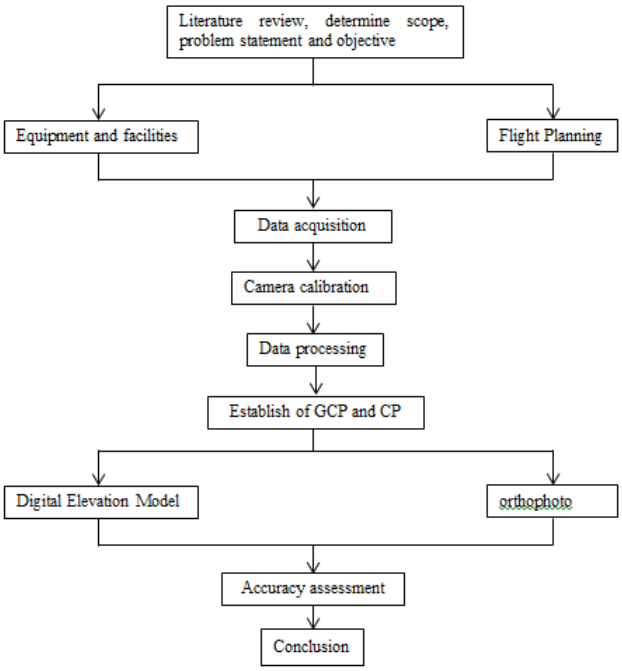


Fig. 1: Flow Chart

3.1. Equipment

There is two camera that been use for this study which Xiaomi yi and Canon Power Shot SX230hs. Both of this camera were digital non metric camera and will be used for this study. The specification of both this camera are shown at table 1 and table 2



Fig. 2: Xiaomi yi

Table 1: specification for Xiaomi yi camera

Kamera Digital	Spesfikasi
Model kamera	Xiaomi yi
Saiz piksel	4608 x 2592
Resolusi imej	12 megapiksel
Penderia	CMOS
Dimensi	4.2 x 2.4 x 1.3 in. (106 x 62 x 33 mm)
Berat	72 g
Memory type	MicroSD
Format File	JPEG, AVI, MAV



Fig. 3: Canon Power Shot SX230hs

Table 2: specification of Canon Power Shot SX230hs

Kamera Digital	Spesifikasi
Model kamera	Conan Powershot XS230 HS
Saiz piksel	4000 x 3000

Resolusi imej	12 megapiksel
Penderia	CCD
Dimensi	4.2 x 2.4 x 1.3 in. (106 x 62 x 33 mm)
Berat	218 g
Memory type	SD/SDHC
Format File	JPEG, AVI, MAV

3.2. Data acquisition

Each UAV flight for aerial data acquisition require flight planning with the help of the autopilot. Planning must follow the fundamental aspects of photogrammetry minimum of 60% overlap and minimum 40% sidelap. Depending on the UAV flights controller, each UAV has its own software for using program the flight path for the autopilot. For S500 UAV it use pixhawk flight controller. Mission planner is used for programming the autopilot for S500. Several factors must be taken into account such as the flight path, altitude, flight area, the distance between two adjacent lines, squeezing and squeezing the tip side. In the study, the low height of the controlled variables. While the distance between the flight path by an area camera views and squeezing the sides. For this study the overlap is 80% and the sidelap is 50%. Table 3 shows the detail information of the flight path for the Canon PowerShot digital camera and camera action XS230HS Xiaomi Xiaomi Yi.



Fig. 5: S500 UAV

Table 3: information of the flight path

Altitude	**60meter**	**80meter**	**100meter**
Distance Travel	4.92km	3.5km	2.93km
No of Line	16	11	9
Distance Between Line	30.49meter	40.66meter	50.82meter
Flight Time	20.30	14.34	12.12

3.3. Establishment of GCPs and CPs

For large format aerial photographs assessment, GCP and CP were established by using rapid static technique and the data obtained were in the form of three dimensional coordinates, that have X, Y and Z coordinates. The obtained control point were used in referencing the geometric positions of feature in photographs and assessed the accuracy of aerial triangulation via different software. Since centimeter level of accuracy required, 15 to 20 minutes observation time was used. After the field operation stage, the stored data was processed and adjusted using Trimble Total Control software. Two reference stations were selected for taking into account the corrections for accurate ambiguity resolution procedure.

3.4. Camera Calibration

Camera calibration process is a process that must be done this because the camera used is not a metric camera. Digital cameras like Xiaomi Yi and Canon Powershot XS230HS are non-metric cameras where the lens is unstable. According to (8) the process of camera calibration needs to be done because to construct the original light ray bonds formed through the center of perspective from the point of image to the point of the object during the making image. There few calibration methods that can be used such as, on-the-job calibration, self-calibration and analytical plumb lines. In this study only the self-calibration bundle adjustment method will be used.
In this study, a three-dimensional field of examination has been developed. The target number for the calibration plate is 100. The calibration plat that consist 36 different height screw that been arrange in matrix order within dimension 0.4 meters x 0.4 meters. Figure 6 shows an example of a dossier or test plate. Note that the scale bar is also placed in the test field to provide a form. Above the skill, the retroreflective target is attached to itEstablishment of GCPs and CPs



Fig. 6: Calibration plate

Both Canon Powershot XS230HS digital cameras and Xiaomi Yi action cameras will be used to photograph the photogrammetry field at a distance of one meter from the camera to the center point of the calibration plate. Before taking any image, a recognizable scale bar value is placed on the calibration plate or the test field. Retro-reflective digital camera. For each of the camera eight photo were taken with the camera in an ordinary landscape position. Each of the camera is then rotate 90˚ for each of the position to regain the main point. Then the image will be processed using Australis Photometric software to obtain the focal distance (f), the offset of the main point (xp and yp), jejarian jungle shoots (k1, k2 and k3), tangents (p1 and p2).

3.5. Processing

The first part of the is a photo-alignment process. Photo alignment process involves tie points automatically by using the filter unchanged. This algorithm will identify the point of bonding is based on the pixels of the same and will be a point of bonding in processing 3D model. Meanwhile, Point Cloud is produced in this section have coordinate and degrees of brightness based on the level of the selected density. In addition, other results that will be obtained in this section are camera calibration parameters, the position of the camera when shooting, interior orientation parameters, the parameters of external orientation and bonding point in the form of a 3D model.
Ground control points must be digitized to produce a mosaic orthofoto. For this study 5 GCP is digitize to be used for processing. Then the process of determining a projection system for orthophoto mosaic of Rectified Skew projection system Orthomorphic (RSO) is performed.
Next is geometric modeling. Geometric modeling process is to strengthen the image of the bond and listed the image based on the position and height of the image. However, the resulting 3D model situation is still not perfect in terms of form and appearance. 3D models formed in geometry modeling are still blurred and less clear. Therefore, the process of forming the texture of 3D surface element model needs to be done and a series of irregular triangle shape (TIN) and orthophoto mosaic which has a perfect surface, smooth and clear.

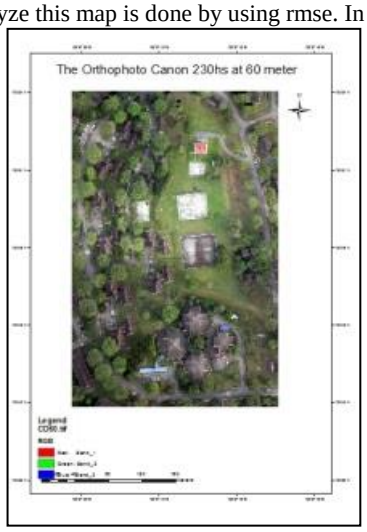
4. Results and Findings

Each of the camera produce six result which divided by two type of image which is orthophoto and DEM. Then each type has three altitude which is 60 meter, 80 meter and 100 meter. Each of the result is then analyse using the RMSE from the CP that been collected earlier.

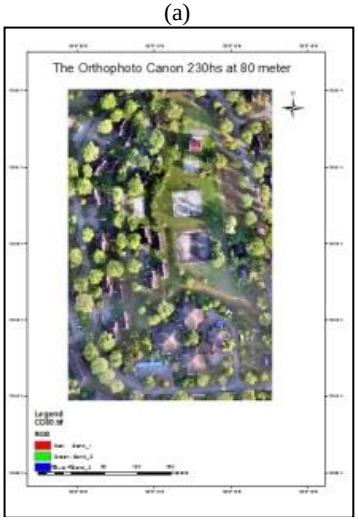
4.1. Orthophoto

One of the result that been produce is orthophoto. This is to show the accuracy of the map in 2 dimensional form which include X and

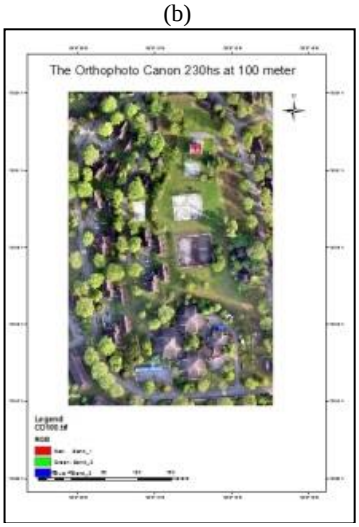
Y. The map is form by mosaic several images and stitch them together to form a larger map. This map can be used to measure distance. To analyze this map is done by using rmse. In this



(a)

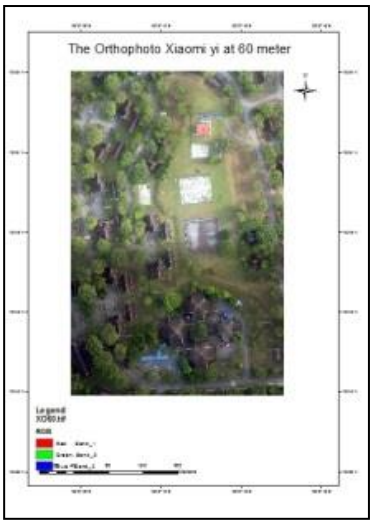


(b)

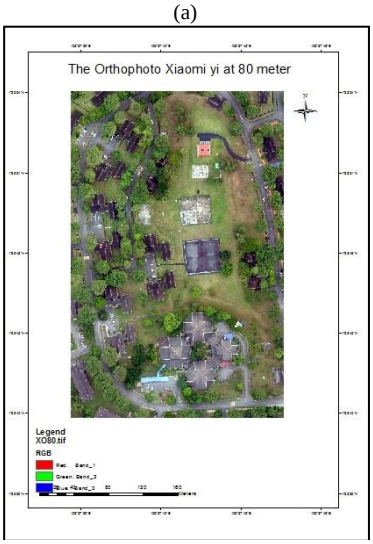


(c)

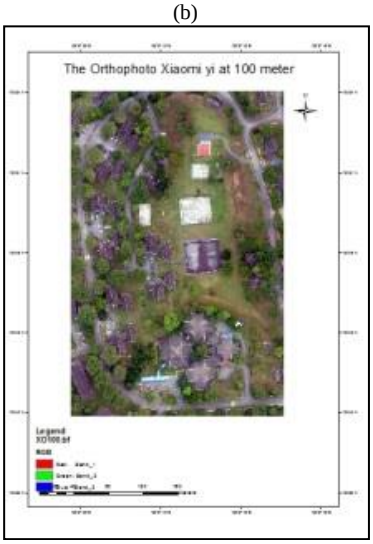
Fig. 7: orthophoto of Canon Power Shot SX230 (a) 60 meter (b) 80 meter (c) 100 meter



(a)



(b)



(c)

Fig. 8: orthophoto of Xiaomi Yi (a) 60 meter (b) 80 meter (c) 100 meter

Figure 7 show the result of orthophoto by Canon Power Shot SX230hs from altitude 60meter, 80meter and 100meter. While figure 8 show the result from Xiaomi yi 60meter, 80meter and 100meter. Both of the camera produce good result with few minor error.

Table 4: RMSE result on orthophoto

	60 meter	**80 meter**	**100 meter**
Canon Powershot XS230HS	0.48629555	0.520166967	0.698629742
Xiaomi Yi	0.391418208	0.403808006	0.51973811

Base on the result on table 2 it show the accuracy of both camera to produce orthophoto. Both camera capable produce orthophoto map with a good result. The accuracy on Xiaomi yi is slightly better than Canon Power Shot SX230hs. Also it show that the accuracy decrease as altitude increase on both of the camera.

4.2.DEM

DEM is a representative of 3 dimensional map which include X, Y and Z. The map was produce by dozen of stereo image. By using triangulation technique it measure the elevation of the terrain on the image. The DEM can be used for surface analysis and water flow modeling. The accuracy of the result is separated by two which is elevation only and 3 dimensional accuracy

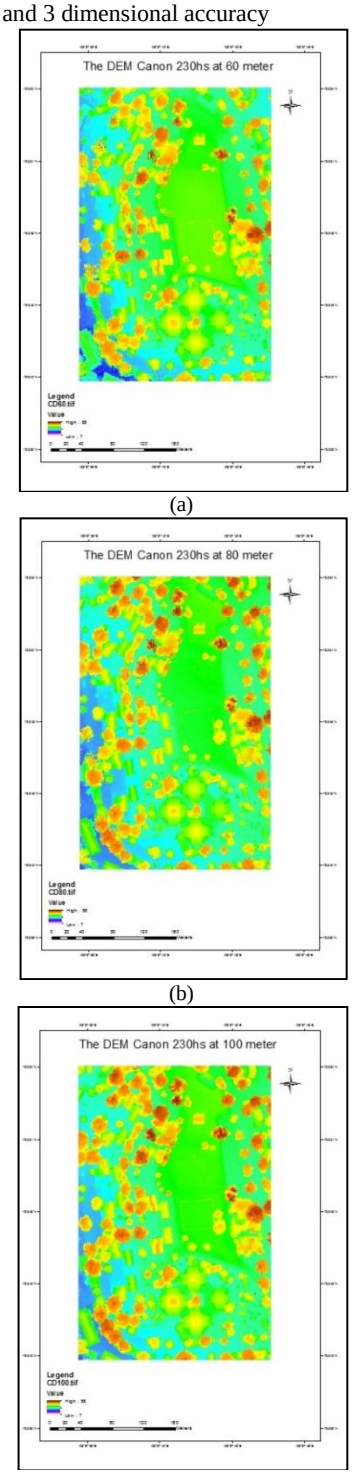


Fig. 9: DEM of Canon Power Shot SX230 (a) 60 meter (b) 80 meter (c) 100 meter

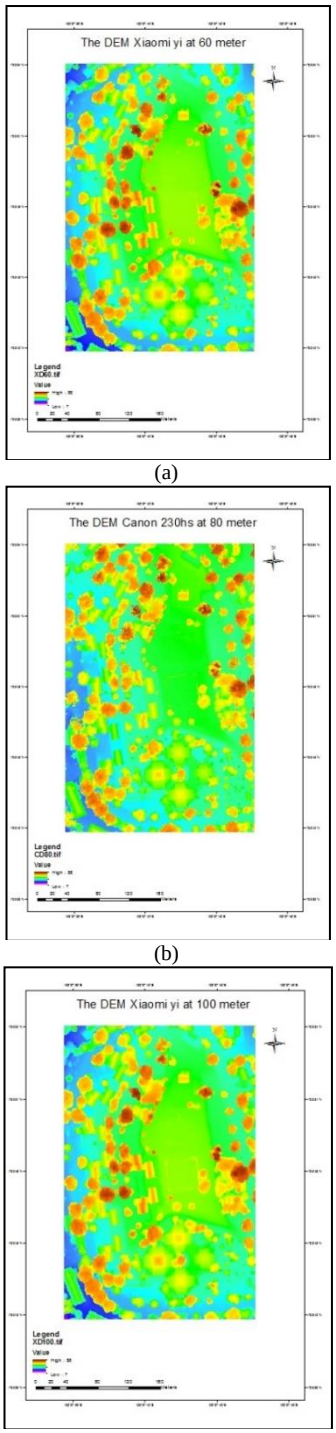


Fig. 10: DEM of Xiaomi yi (a) 60 meter (b) 80 meter (c) 100 meter

The figure 8 show the result of DEM by using Canon Power Shot SX230hs and figure 9 is DEM for Xiaomi yi. The colour on the map show the terrain height where brown is the highest at 58 meter and the lowest is pink at 6 meter. The result show that Canon Power Shot SX230hs produce more detail compare with Xiaomi yi.

Table 5: RMSE result on DEM

	60 meter	**80 meter**	**100 meter**
Canon Powershot XS230HS	0.552069978	1.724907303	3.417273542
Xiaomi Yi	0.57616149	0.499077812	4.47488752

Table 6: RMSE result on 3 dimensional

	60 meter	**80 meter**	**100 meter**
Canon Powershot XS230HS	1.072236945	2.423537045	3.903569092
Xiaomi Yi	0.979969497	0.89049602	4.99462563

Based on table 5 80 meter the Xiaomi yi camera has better accuracy than Canon Power Shot SX230hs while 60 meter both the camera give almost similar accuracy. this due wide angle of the Xiaomi yi lens. However at 100 meter the Canon Power Shot SX230hs give better accuracy than Xiaomi yi due high ground resolution.

5. Conclusion

Visually both camera give camera can produce orthophtoto and DEM. For the accuracy the orthophoto of the Xiaomi Yi give a slight better accuracy compare to the Canon Powershot XS230HS. While for the DEM the experiment show that the Xiaomi Yi has a better accuracy at lower altitude than the Canon Powershot XS230HS while high altitude Canon Power Shot SX230hs produce a better accuracy. The result of the study shown that that wide lens camera like Xiaomi yi only suitable for low alttitude UAV while camera that has narrower field of view like Canon Power Shot SX230hs is more suitable for high altitude UAV. Thus a fixed wing UAV that can only fly higher than 100 meter altitude can only use Canon Power Shot SX230hs for the topographic mapping. While Xiaomi yi a much suitable for close range photogrammetry like in-frastructural monitoring.

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