Assessment of The Accuracy of Two UAVs Images Obtained by Ux5 and Aibotix Types

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Abstract: ***Unmanned Aerial Vehicles (UAVs) have made it possible to obtain images for all types of mapping data in fast and economic way. However, it is necessary to know the accuracy of the data and if it is within the allowable limits. This study aims to compare the accuracy of digital surface model (DSM) for an area that is derived from using two UAVs types. Ux5 and Aibotix. Both UAVs were used to obtain coordinates of reference points in order to determine the accuracy of the imagery produced from them. The coordinates were compared two times, one from the imagery acquired with a digital camera on board(Ux5) and second from imagery acquired withal digital camera on board Aibotix type. The UAVs flight height was100 m above ground. Twelve ground control points (G.C.Ps)marked by checkerboard mat were considered for data comparison. The horizontal coordinates (E,N) were obtained from the other rectified images derived from the two UAV types. The reference coordinates of the G.C. Paused for comparison were determinedly using G.P.S Leica Viva GNSS receiver with horizontal accuracy of (±3mm + 0.1ppm).The RMSE found to be σ∆E=±1.85cm and, σ∆N=±2.58cm for easting and northing respectively with total RMSE = ±3.17cmfor the Ux5, and found to be σ∆E=±2.15cm and, σ∆N=±3.67cm with total RMSE = ±4.25cm for the Aibotix. According to standards of American Society for Photogrammetric and Remote Sensing (ASPRS)andNational Standard for Spatial Data Accuracy2014(NSSDA),the horizontal accuracy for both Ux5 and Aibotix reported at the 95% confidence level can be categorized as class I and class II respectively. That indicate that the image obtained from Ux5 is more precise than Aibotix one.***

Keywords: ***Ux5, Aibotix, Accuracy of UAV Imagery, Checkerboard Mat.***

I. INTRODUCTION

Many researchers and civil engineers use other photos as an essential source for data used in design and execution of many projects, as well as to periodically follow up the progress of the works. Therefore, it is required to know the accuracy of the acquired information and that if it is within the allowable limits. In order to obtain a map, there are several methods that can be used to fulfill high precision results, such as the case of Terrestrial Laser Scanning (TLS), Global Navigation Satellite Systems (GNSSs), airborne sensors, light detection and ranging (LIDAR) Total Stations (TSs) or photogrammetric cameras. Unmanned Aerial Vehicles (UAV) photogrammetric has opened a variety of new applications in the field of close-range photogrammetric by combining aerial and terrestrial photogrammetric techniques to offer the advantages of both.

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Thus, the application of UAV photogrammetric in the field of civil engineering can be located between techniques using traditional terrestrial systems and techniques based on photogrammetric from images taken from classic aircraft, Representing An economically applicable alternative, [3]. Many such cases, UAVs are better than others because they require less time for data collection and reduce costs compared to the use of traditional manned aircrafts. The instrument used is more commonly known as drones, it was introduced to the wide variety public developments for military reasons. UAVs immediately became beneficial information source for many of needs such as: damage evaluation of buildings after natural disasters like lava and earthquakes[2].It was acquired also for precise mapping by using different classification processes with fast and precise 3D renew archaeological building or other manmade structures like ancient architectural. Using UAVs display numerous advantages some of which are the easy usage, relatively low cost and the on-demand flights. The UAV shave been already applied in many times at archaeological projects worldwide by researchers to interpret, identify, document archaeological sites by digitally reconstruct. The UA Vshave many capabilities and their multiple applications have been recently published. There are different kinds of drones like Ux5 and the Aibotixthat which were used in this studying figure (1).

(a) (b)

Figure 1. Illustration of UAVs (A) The Ux5 and (B) The Aibotix

II. THE UAVs CHARACTERISTICS OVERVIEW

The two UAV sthat are employed in this studying, are theUx5 and Aibotix specifications **are** explained in tables (1) and (2) respectively. The Ux5 hasa ground control station (GCS) which is used to control the UX5 aerial imaging rover from the ground and support autonomous flight. The UAV flied over a study area at 100 above the ground at a speed of 22 m/s. It carried a camera (Sony a5100**)** with 23.4 megapixels, focal length 15 mm, that provides sharp, detailed images.

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The standard RGB solution includes a UV HAZE 1 filter. The optional NIR (near infrared) solution is for use in specialized applications such as agriculture, it is manufactured in California USA.

Table [1] Specifications of Ux5

Type	Fixed wing
Weight	2.5 kg
Wing area	34 dm^2
Wingspan	1 m
Dimensions	100 cm x 65 cm X 10.5 cm (39.37 in x 25.59 in x in)
Material	EPP foam; Carbon frame structure; Composite elements
Propulsion	Electric pusher propeller; brushless 700 W motor
Camera	23.4 MP mirrorless APSC with custom 15 mm lens
Battery	14.8 V mAh
Controller	Trimble Tablet Rugged PC
Pixel size	2 cm at 100m height

Another UAVs are employed in this studying, is the **Aibotixits specifications are** explained in table (2).It comes with six arms rotor blades with electrics powered. The Aibotix equipped with aground control unit and is able to fly in manual mode or sported mode and It carried a camera farm Sony with 16 megapixels,[4] The Aibotix flied over a study area at 100 m above the ground at a speed of 16.7 m/s, it is manufactured in Germany.

Table [2] Specifications of Aibotix

Type	six arms
Weight	2.555kg
Flight weight	3,700 – 6,500Kg (dependent on payload and batteries)
Wingspan	1 m
Dimensions	105 cm x 100 cm X 45 cm (39.37 in x 25.59 in x in)
Material	CFK (carbon), protected rotor blades
Max. speed	60km/h
Camera	Sensors has GPS, Gyroscope, 8 Ultrasonic sensors, Smart-camera system with DSP(16.1MP)
Battery	18.5 V
Controller	Remote control, Tablet-PC (optional)
Pixel size	3 cmat 100m height

A. Application Area

The study was applied to an area lies in southeast Cairo Egypt and is located between 30°00 20.13''and 29° 59 57.56''N latitude sand 31°31 40 57.73''and 31° 41 23.82'' E longitudes, UTM Zone 36N. The area covers about 500X500 m^2. The study area is characterized by nearly horizontal and level edterrainas shown in figure (2).

Figure 2 Location of Application Area

III. METHODOLOGY

The images used in this work were taken from UAVsUx5 and Aibotix. The images at the specified area were used for comparing the accuracy of the UAVs. Twelve ground targets (checkerboard mat with a center point) were used as G.C.P for comparison and were surveyed by using differential GPS. The targets specifically designed on the ground markers to meet our accuracy requirement. The 12 control points and were identified into our images through modeling software. It could be accurately compare the UAVs photogrammetric E, N data with the differential GPS E, Ndata at highly reliable common points. The differential GPS coordinates are measured with relative accuracy using stop-go method.

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Agisoft software was using ArcMape10.3and ERDAS Imagine 9.2 for image processing. Then RMSEs were calculated for both images from the two UAV sand results were compared with National Standard for Spatial Data Accuracy (NSSDA) and the (ASPRS).

A. Target

To create a quality ground control points or check points G.C.P to be used for drone mapping software, there are 4 key things to be considered. a) Use a large, clear targets, the ideal GCPs targets could be a large X marked on the ground, a circular target with a center point or a checkerboard mat. It is important to make sure that the targets have high contrast colors like black & white and that it is sufficiency enough to be clear visible from the flight altitude's,

Figure (3). b) Measure the GCP center with high precision GPS. The requirement is an extremely precise GPS measurement to generate a satisfied reference ground control point. c) Evenly Spread the GCPs through the application area, A good strategy is to distribute the GCPs location in the 4 corners of area and the center. As you place your GCPs make sure you leave a minimum 15m buffer from the GCPs to the boundaries of the area. d) The GCPs markers must be unobstructed and clearly visible, to create quality GCPs for drone mapping, to be successfully processed [1]

Figure 3. Target Rubber Sheet90*90cm

B. Absolute and Relative Accuracy

The **absolute** accuracy is the degree to which the measured **position** of a point on a map corresponds to its actual position in the real world. To possess high degree of absolute accuracy the map must has the correct shape, size, and location when compared with the real-world figure (4). There for the **G.C. Ps**are required to make maps with high absolute accuracy**.** The **relative** accuracy is the degree to which the **distances** between points on a map correspond to the actually distances between those points in the real-world. To have high relative accuracy it does not matter where the map is located as long as the its shape and size s are correct, figure (3). There for the **GCPs** are not required to make maps with high relative accuracy [1]**.**

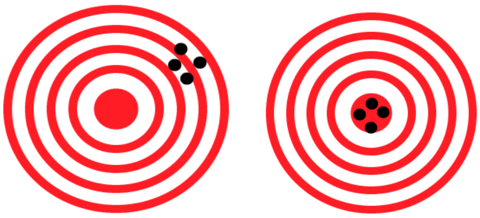

Figure 4. The Relative and Absolute Accuracy

C. Field Work:

The images used in this work were taken from UAVs Ux5 and Aibotix, the flight altitude was 100m above ground level. A surface area of 500×500 $m^2$was covered by each image with ground resolution distance of2.0 and 3.0 cm respectively. These values correspond to the UAV imagery, located at100m elevation for all the study area. According to the flight altitude, weather conditions and UAV speed at the flight time, the shutter speed was adjusted to reduce the blurring effect on the images output. **For Ux5**the flight plan(F.P)was carried out in navigation mode and consisted of 23- flight lines, and a total of 426 images were selected to carry out all the imagery projects. The camera was adjusted every two seconds by a controller on the UAV and the flight speed was set to obtain forward and side overlaps of 80 and 60% respectively. **For Aibotix** the same procedures at above are carried out 10- flight lines were performed and the 464 images were selected to perform the photogrammetric project. The camera was modified through the controller on the UAVs to acquire the forward and side overlaps of 80 and 60% respectively. Prior to the images acquisition, 12 targets were distributed on the studied area for the purpose of assessing the accuracy of the DSM and other photos (Check Points, GCPs). The targets consisted of rubber sheet size (90×90cm) checkerboard mat figure (2).The locations of these targets are shown in figures (5)and(6).By using stop-go method to acquire the geodetic and grid coordinates of twelve targets located in tested area. The data was collected using Leica Viva GNSS receiver. Leica Viva Global Navigation Satellite System (GNSS) receiver is a multiple-frequency GNSS receiver, which is powerful, flexible, and reliable. It can track all GPS signals (L1 C/A, L2C, L2E, and L5 full cycle carrier). It can produce all type of measurement data and generate Real Time Kinematic RTK, Differential Global Positioning System DGNSS, and National Marine Electronics Association NMEA outputs. A fixed station with known WGS84 coordinates, located on the middle of the study area it was used as a reference station. The known coordinates of reference station according to WGS84 ellipsoid are:

Latitude = 30º 00' 10.35" N
Longitude = 31º 41' 04.05" E
Ellipsoidal Height = 46.70 m.

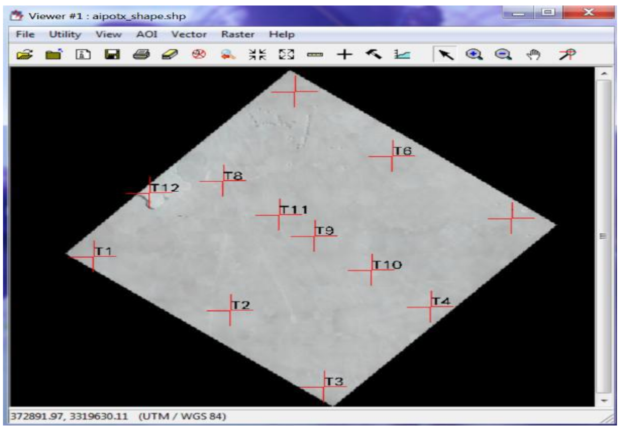

Figure 5. The Imagery Ux5 with 12CPs

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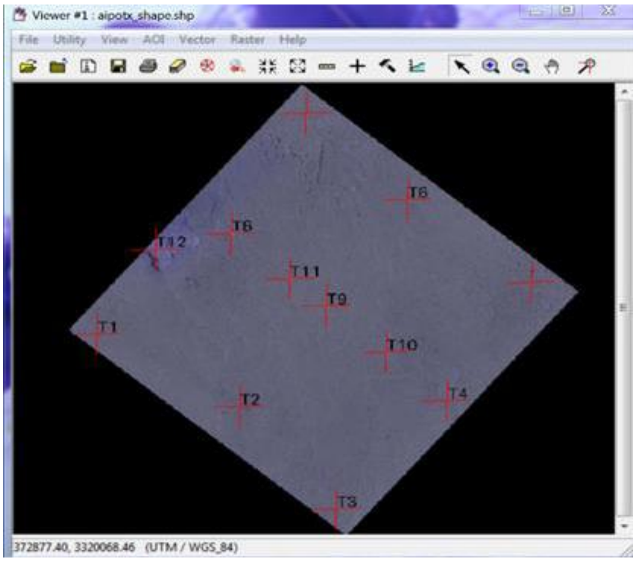

Figure 6. The Imagery Aibotx with 12CPs

The reference station was occupied by another Leica Viva GNSS receiver, during the data collection for the twelve targets stations. The maximum baseline between the reference station and the selected targets stations, was about 300 m. The logged observations of the twelve stations and reference points, were imported to Leica Geo Office software, to process the raw data of twenty stations relative to the reference station. The processing parameters were, cut off angle of 15º, using broadcast ephemeris, troposphere model of Hopfield, and fix ambiguity up to10 km. Table (3) shows the obtained coordinates of the twelve target stations, in both WGS84 geodetic coordinated and grid UTM36 coordinates.

Table [3]The Geodetic and Grid Coordinates of The Twelve Target Stations

Point ID	Geodetic Coordinates		Grid Coordinates	
	Latitude	Longitude	Easting /M	Northing /M
T1	31° 40' 59.301"	30° 00' 7.415"	372988.811	3319743.505
T2	31° 41' 6.651"	30° 00' 3.827"	373184.479	3319630.790
T3	31° 41' 11.684"	29° 59' 58.685"	373317.520	3319470.951
T4	31° 41' 17.3099"	30° 00' 4.199"	373470.208	3319638.968
T5	31° 41' 21.511"	30° 00' 10.241"	373584.901	3319823.676
T6	31° 41' 15.119"	30° 00' 14.395"	373415.101	3319953.515
T7	31° 41' 9.871"	30° 00' 18.722"	373276.016	3320088.330
T8	31° 41' 6.127"	30° 00' 12.600"	373173.539	3319901.020
T9	31° 41' 11.039"	30° 00' 8.940"	373303.857	3319786.840
T10	31° 41' 14.118"	30° 00' 6.646"	373385.547	3319715.276
T11	31° 41' 9.131"	30° 00' 10.331"	373253.225	3319830.247
T12	31° 41' 2.232"	30° 00' 11.751"	373068.877	3319876.083

Therefore fermenting processing was performed for both images using the four G.C.Ps at the corners. The alignment of the images by feature identification and feature matching was carried out using the software package Agi soft Photo Scan Professional.

D. Accuracy Assessment

The accuracy of all imagery projects was evaluated using the surveyed target points GCPs, using the typical root mean square error (RMSE).To this end, the GCP swore identified in the or the images through Inquire cursor tool at ERDAS IMAGIN 9.2 Software and their coordinates were compared to the surveyed GNSS coordinates, resulting in $RMSE_X$, $RMSE_Y$, and $RMSE_{XY}$ horizontal accuracy were measures performed, Table(4) shows coordinates comparison between those obtained from UTM_{36} GNSS and UAVUx5image.

Table [4] Show, Image UTM_{36} and GNSS Coordinates for Comparing With Ux5

UAV/ Ux5						
ID	X field	Y field	X image	Y image	Δx(cm)	Δy(cm)
T1	372988.811	3319743.505	372988.827	3319743.494	1.60	-1.09
T2	373184.479	3319630.790	373184.486	3319630.753	0.71	-3.73
T3	373317.520	3319470.951	373317.489	3319470.986	-3.13	3.51

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T4	373470.208	3319638.968	373470.194	3319638.998	-1.40	3.03
T5	373584.901	3319823.676	373584.912	3319823.694	1.09	1.75
T6	373415.101	3319953.515	373415.101	3319953.512	0.03	-0.25
T7	373276.016	3320088.330	373276.008	3320088.346	-0.80	1.61
T8	373173.539	3319901.020	373173.550	3319901.047	1.09	2.69
T9	373303.857	3319786.840	373303.886	3319786.831	2.89	-0.89
T10	373385.547	3319715.276	373385.532	3319715.300	-1.45	2.42
T11	373253.225	3319830.247	373253.251	3319830.280	2.55	3.29
T12	373068.877	3319876.083	373068.852	3319876.047	-2.51	-3.61
$RMSE_X$ **1.85**cm						
$RMSE_Y$ **2.85**cm						
$RMSE_{XY}$ **3.17** cm						

Theresulting of comparing between other images coordinates and 12 GCP targets which surveyed GNSS coordinates and the of different values of easting and northing are shown in figure (7) Δx and figure (8) Δy for UAV ux5

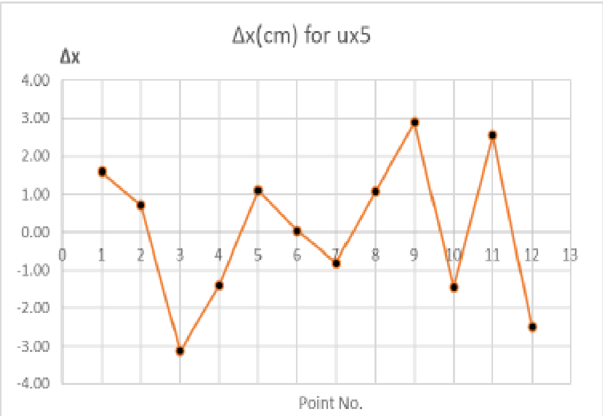

Figure 7. Illustrated the Δx of Ux5 Imagery

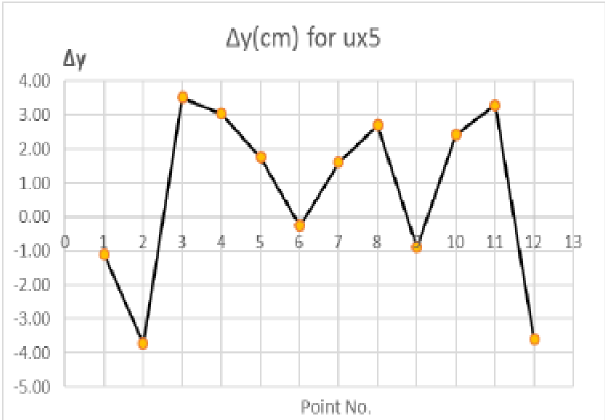

Figure 8. Illustrated the Δx of Ux5 Imagery

Table (5) shows, image UTM_{36} and GNSS coordinates for comparing with UAV Aibotix.

Table [5] Show, Image UTM_{36} and GNSS Coordinates for Comparing with Aibotix.

UAV/Aipotix						
ID	**X field**	**Y field**	**X image**	**Y image**	**Δx(cm)**	**Δy(cm)**
T1	372988.811	3319743.505	372988.833	3319743.527	2.20	2.21
T2	373184.4789	3319630.79	373184.501	3319630.827	2.21	3.67
T3	373317.5203	3319470.951	373317.502	3319470.977	-1.83	2.61
T4	373470.208	3319638.968	373470.221	3319639.009	1.30	4.13
T5	373584.9011	3319823.676	373584.939	3319823.743	3.79	6.65
T6	373415.1007	3319953.515	373415.125	3319953.547	2.43	3.25
T7	373276.016	3320088.33	373276.004	3320088.314	-1.20	-1.59
T8	373173.5391	3319901.02	373173.558	3319901.057	1.89	3.69
T9	373303.8571	3319786.84	373303.8877	3319786.882	3.06	4.20
T10	373385.5465	3319715.276	373385.541	3319715.31	-0.55	3.42
T11	373253.2255	3319830.247	373253.245	3319830.289	1.95	4.19
T12	373068.8771	3319876.083	373068.89	3319876.073	1.29	-1.01
RMSEX **2.15**cm						
RMSEY **3.67**cm						
RMSEXY **4.25**cm						

The different values of easting and northing coordinates for the other images project and the targets coordinates are illustrated at figure (9) Δx and figure (10) Δy for UAV Aibotix

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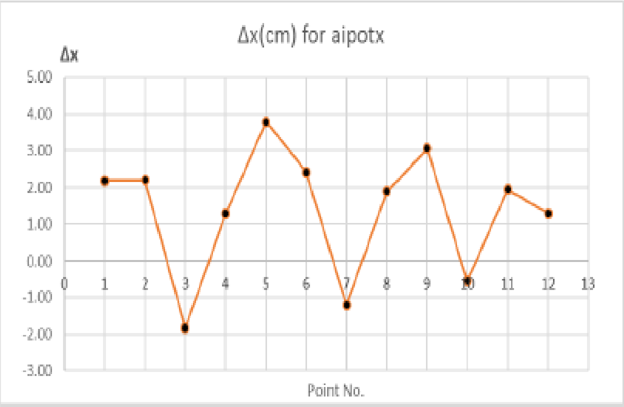

Figure 9 the value Δx of Aibotix Imagery

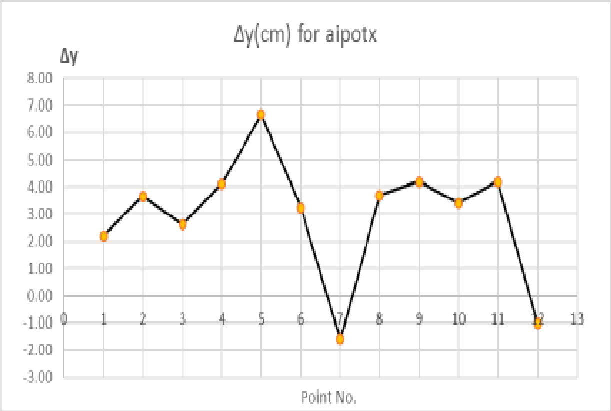

Figure 10 the value Δy of Aibotix Imagery

IV. COMPARISON OF DSM HORIZONTAL ACCURACY FROM THE UAVS

This study aims to evaluate the horizontal accuracy of digital surface model (DSM) derivatives from UAVs photogrammetric project applied to studying area together with ground surveying (GCP) observed, using differential (GPS). The results showed that $RMSE_X =$**±1.85** cm, RMSEY=±**2.85** cm and the total of $RMSE_{XY=}$± **3.17** cm for theUx5 asthehorizontal (radial) accuracy at the 95% confidence

level=$RMSE_{XY}$×**1.73**as documented according to the National Standard for Spatial Data Accuracy(NSSDA) and (ASPRS)table(6).The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. The Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value[5].Therefore, the horizontal accuracy for Ux5reported at the 95% confidence level considered as **class I**.

Table 6. Horizontal Accuracy/Quality for Digital Ortho photos [4]

orthophoto pixel size	Horizontal Data Accuracy class	RMSEx or RMSEy (cm)	RMSEr (cm)	orthophoto mosaic seamline Maximum mismatch (cm)	Horizontal Accuracy at the 95% confidence level (cm)
2.5-cm (-1in)	I	2.5	3.5	5	6.1
	II	5	7.1	10	12.2
	III	7.5	10.6	15	18.4
5-cm (-2in)	I	5	7.1	10	12.2
	II	10	14.1	20	24.5
	III	15	21.2	30	36.7
7.5-cm (-3in)	I	7.5	10.6	15	18.4
	II	15	21.2	30	36.7
	III	22.5	31.8	45	55.1
15-cm (-6in)	I	15	21.2	30	36.7
	II	30	42.4	60	73.4
	III	45	63.6	90	110.1
30-cm (-12in)	I	30	42.4	60	73.4
	II	60	84.9	120	146.9
	III	90	127.3	180	220.3
60-cm (-24in)	I	60	84.9	120	146.8
	II	120	169.7	240	293.7
	III	180	254.6	360	440.7
1-meter	I	100	141.4	200	244.7
	II	200	282.8	400	459.5
	III	300	424.3	600	734.3
2-meter	I	200	282.8	400	489.5
	II	400	565.7	800	979.1
	III	600	848.5	1200	1468.6

The $RMSE_{X=}$±**2.15** cm, RMSEY= ±**3.67** cm and the total of $RMSE_{XY=}$± **4.25** cm for the Aibotx, therefore, the horizontal accuracy[5]for (UAVs) Aibotx reported at the 95% confidence level considered as **class II** according to table (6)

V. CONCLUSION

As a newly developed technique, UAVs have extended and enriched the measurement tools for producing high confidence level of accuracy according to the National Standard for Spatial Data Accuracy(NSSDA).The result of this studying showed that the $RMSE_{XY=}$±**3.17** cm for the UAV ux5,reported at the 95% confidence level satisfies **class I**.

the $RMSE_{XY=}$±**4.25** cm for the UAV Aibotix, reported at the 95% confidence level satisfies **class II**. It means that the UAV Ux5 image is more accurate than the UAV Aibotix image when flight height is 100 m and ground resolution 2 and 3cm respectively and there is some of advantages that can be mentioned as follows:

- Drones are aircraft devices that are capable of flying and carrying materials above the ground (sensor-camera...etc.)
- The controllers of an unmanned aerial vehicle can be both either an automated set of computers or a human operator and the components of these devices are communication systems, a ground-based controller, and unmanned aerial equipment

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- Drones provide useful missions to prevent accidents, injuries, and hazards when it involves navigating in an environment that is not suitable for human survival,
- The spatial resolution of the images derivate from drones about (2..3)cm therefore it has capability to produce the accurate topographic large scale map for multi-purpose
- Drones are now very popular because mass media networks sponsor its functionality and efficiency when capturing videos or images
- On the other said there are troubles in drones that affects user's navigation routine,

A local government from time to time restricts or prevent the use of drones when there is an ongoing military conflict. Drones sometime blocked from get in a restricted zone such as military area.

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