Positional Accuracy Comparison of a DJI Inspire 1 and a Sensefly eBee

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Introduction:

Drone technology has been developed and put to use over the battlefield for more than 20 years now by the U.S. military. Drones piloted by operators over the next hill or from the other side of the planet have saved many American and civilian lives as well as tracked down some of the most highly valued targets in our country's current conflicts. Drone technology is quickly being adapted to serve in civilian uses in the hopes that it will revolutionize surveying and mapping, civil infrastructure, mining, construction, utilities, law enforcement, and precision agriculture the way that it has modern warfare. Over the past five years or so, civilian drone imagery collection has grown rapidly. This sudden inflation in the use of drone remote sensing is because of technological advances and miniaturization of computer technology, battery technology, global positioning systems, inertial measurement units, and sensors. (Tully, 2017; Abdullah, 2014) Tully goes on to emphasize that advances in photogrammetry software have made drone remote sensing so easy that nearly anyone can do it. (Tully, 2017)

For the past 10 years or so, my own path has followed that of drone development. I got my start in drones in the U.S. Air Force as a Predator UAV sensor operator. (see figure 1) After about 5 years of flying Predators in war zones like Afghanistan, Iraq, Somalia, and Yemen I had seen the power and potential of this technology first hand. After getting out of the Air Force, I wanted to ensure that I would be part of the effort to adapt the technologies behind the drones that I flew in the military to civilian uses. I went to the University of North Georgia and earned a bachelor's degree in GIS while helping to incorporate drone mapping into their GIS curriculum. There, I learned a lot about using drone collected imagery to create orthoimages and digital surface models of areas up to several hundred acres in size. I am now a GIS analyst at an engineering firm and I am starting a drone mapping initiative within the company to add value to many of our existing projects and help us out compete other firms and win upcoming work.

Figure 1. MQ-1 Predator Drone

Drones Used:

In my civilian work at UNG as well as the engineering company that I currently work for, I have been fortunate to use two distinctly different models of drones to produce very similar mapping products. While at UNG, I produced orthoimages and digital surface models of areas of the campus from imagery that I collected with a Sensefly eBee fixed wing drone (Figure 2). The eBee is marketed as a “professional grade” drone and currently sells for around $12,500. It can only be purchased at places like survey equipment companies. The eBee has a 18.2 megapixel RGB camera and an integrated GPS/IMU system. It’s advertised to have a horizontal accuracy down to 3 cm and a vertical accuracy down to 5 cm. My experience with the eBee has been; used the eBee in undergraduate remote sensing projects at the University of North Georgia, created a full 3D model of the UNG Gainesville campus Science building, created a full 3D model of the UNG Oconee campus, and helped implement the drone into GIS instruction at UNG.

I’ve started producing orthoimagery and digital surface models in my current drone initiative with a DJI Inspire 1 quadcopter drone. (Figure 3) The Inspire 1 costs around $2,000 and can be purchased from the DJI website. It’s marketed as a “consumer grade” drone. It has a 12.4 megapixel camera, GPS positioning, and dual inertial measurement units and compasses. My experience with the Inspire 2 is; I have completed a full 3D model of a 360 acre dry lake bed in South Georgia for an ecological study, 90 acres of downtown Portland, Maine modeled for a visibility analysis, and a 3 acre environmental remediation site modeled for detailed contour analysis.

Figure 2. Sensefly eBee fixed wing drone

Figure 3. DJI Inspire 1 quadcopter drone

With both drones, I have incorporated ground control points from around the study areas and have used Pix4D Mapper photogrammetry software to process the drone collected images into orthoimagery and digital surface models. Positional accuracy is important to consider in professional mapping work. Positional accuracy is defined as "The degree of compliance with which the coordinates of points determined from a map agree with the coordinates determined by survey or other independent means accepted as accurate". (Congalton & Green, 2009)

It has unfortunately become the tend to produce drone mapping products and simply state that the products have the positional accuracy stated in the material that came with the drone. These accuracies are usually the best-case scenario of what could be possible with the drone. The actual accuracy will be significantly less in most real-world situations (Abdullah, 2017). Before this project, I had never done a formal accuracy assessment for either the eBee collected final products or the Inspire 1 collected products. However, the resulting accuracies of the final products seemed surprisingly similar.

This leads to the question; is it necessary to spend thousands of more dollars to purchase a professional grade drone like an eBee for professional mapping work when a consumer grade drone like an Inspire 1 will provide very similar results? In this project, I conducted accuracy assessments of orthoimagery and digital surface models that were generated from imagery collected by an eBee and an Inspire 1 of the same study site and processed in the same software, on the same computer. The imagery from both drones was collected so as to produce 1 inch spatial resolution red, green, blue imagery. The frames of the imagery from both drones had an 80% front lap and an 80%

side lap. The accuracy assessments were compared to determine whether the eBee has a higher positional accuracy than the Inspire 1. I leave the determination of the cost-benefit analysis to the reader.

Maune (2007), Campbell & Wynne (2011), and Congalton & Green (2009) discuss many of the techniques and methodologies of positional accuracy assessment used for more established types of remote sensing such as satellite and airborne. They all begin their discussions of accuracy assessment with a distinction between positional accuracy and thematic accuracy of mapping products. This is an important distinction to be made in the definition of the objectives of the project. I am not interested in thematic classifications of objects after the generation of the orthoimagery and digital surface models for the purposes of this project.

Previous Studies:

RMSE error calculations were used in the accuracy assessments done in the two previous studies of drone collected imagery mapping products that I studied in my literature review for this project. Paudie and Coakley (2013) provide good details of a study that they conducted in 2013 using a C-Astral Bramor fixed wing drone. Abdullah (2017) describes a similar study that he carried out in 2016 using a Kespry quad copter UAS. See Table 1 for details of the two studies that I drew methodologies from.

• Paudie Barry and Ross Coakley, 2013	• Qasim Abdullah, 2017
• C-Astral Bramor fixed wing drone	• Kespry quad copter UAS
• Camera – 24 megapixels	• Camera – 24 megaipxels
• Site size – 2 Ha (4.9 acres)	• Site size – 31 acres (12.5 Ha)
• 9 ground control points and 45 check points used	• 29 ground control points and 20 check points used
• 80% front and 80% side overlap	• Front and side lap were not stated
• Agisoft Photoscan used to process the imagery	• Pix4D Mapper used to process the imagery
• Resulting horizontal RMSE – 0.023 m (0.08 ft)	• Resulting horizontal RMSE - .29 ft (0.09 m)
• Resulting horizontal Accuracy 95% - 0.041 m (0.13 ft)	• Resulting horizontal accuracy 95% - .49 ft (0.15 m)

Table 1. Details of two previous UAS accuracy assessments. (Paudie and Coakley, 2013; Abdullah, 2017)

Both studies used similar methodologies and achieved impressive accuracies. Of note is the large difference of ground and check points that were used in these studies. Abdullah mapped a much larger site and used about three times as many ground control points. Yet, he used less than half the number of check points to assess the accuracy. Two major differences in the studies are that in one, a fixed wing drone was used, a quadcopter in the other. Also Barry and Coakley used Agisoft Photoscan to process the imagery. Abdullah used Pix4D Mapper.

Study Site:

The study site for this project was the science building on the University of North Georgia, Gainesville, GA campus. (See figure 4) I had flown over the campus before and have a good grasp of all flight obstructions in the area. I originally planned to fly the field on the North side of the campus. However, I ended up not being able to fly the eBee over that field because of maintenance issues with the eBee. In order to be able to continue the project, I chose to use the science building as the study area because I had previously flown this area with the eBee and had data from that flight that matched the parameters of this project. The study area is roughly 3.6 acres in size.

Permissions:

After briefing campus security on the specifics of the project, I was granted permission to fly drones in this study area for the duration of the project. I also obtained special permission from campus security to get on the roof of the science building and place control markers for the study. The study area is about two and a half miles from the Gainesville airport. The new FAA Part 107 laws state that if you intend to fly within 5 miles of an airport, you have to request permission from the airport. I sat down with the Airport Manager at the Gainesville airport and got his buy in on the project. Per his request and the FAA rules I called him each time before I flew so that he could inform his controllers that my drones will be in the air in the area of the campus.

Figure 4. Study area.

Control Point and Check Point Collection:

Control points were used in the actual processing of the point clouds to ensure that they were in the correct location. Check points were used after processing was completed to assess the accuracy of the final products. Because I was using data from a flight that I had already done, I needed to measure the location of features in the study area that could be identified in the old eBee imagery, as well as the new Inspire 1 imagery such as prominent seams in sidewalks, utility box covers, and drains on the roof of the building. (see figure 5) To collect the control and check points, I used a Tremble Geo7X GPS unit with an external antenna on a pole. (Figure 6)

Figure 5. Daniel Hulsey collecting a control point on a sidewalk joint.

Figure 6. Tremble Geo7X

This allowed me to achieve a very high precision location for each measured location. The Geo7X that I used for this project was from the engineering company that I work for. When collecting the points, I collected at least 100 points at each location. After collection, the points were post processed in Tremble's post processing service to correct for ionospheric and tropospheric errors as well as clock errors. (Van Sickle, 2015) One source of error that I was especially cognizant of trying to avoid when measuring the locations was multipath error when taking points near the walls of the science building. Because this was a small site at 3.6 acres, 9 control points were used for processing and 8 check points were used for accuracy assessment. (see figure 7)

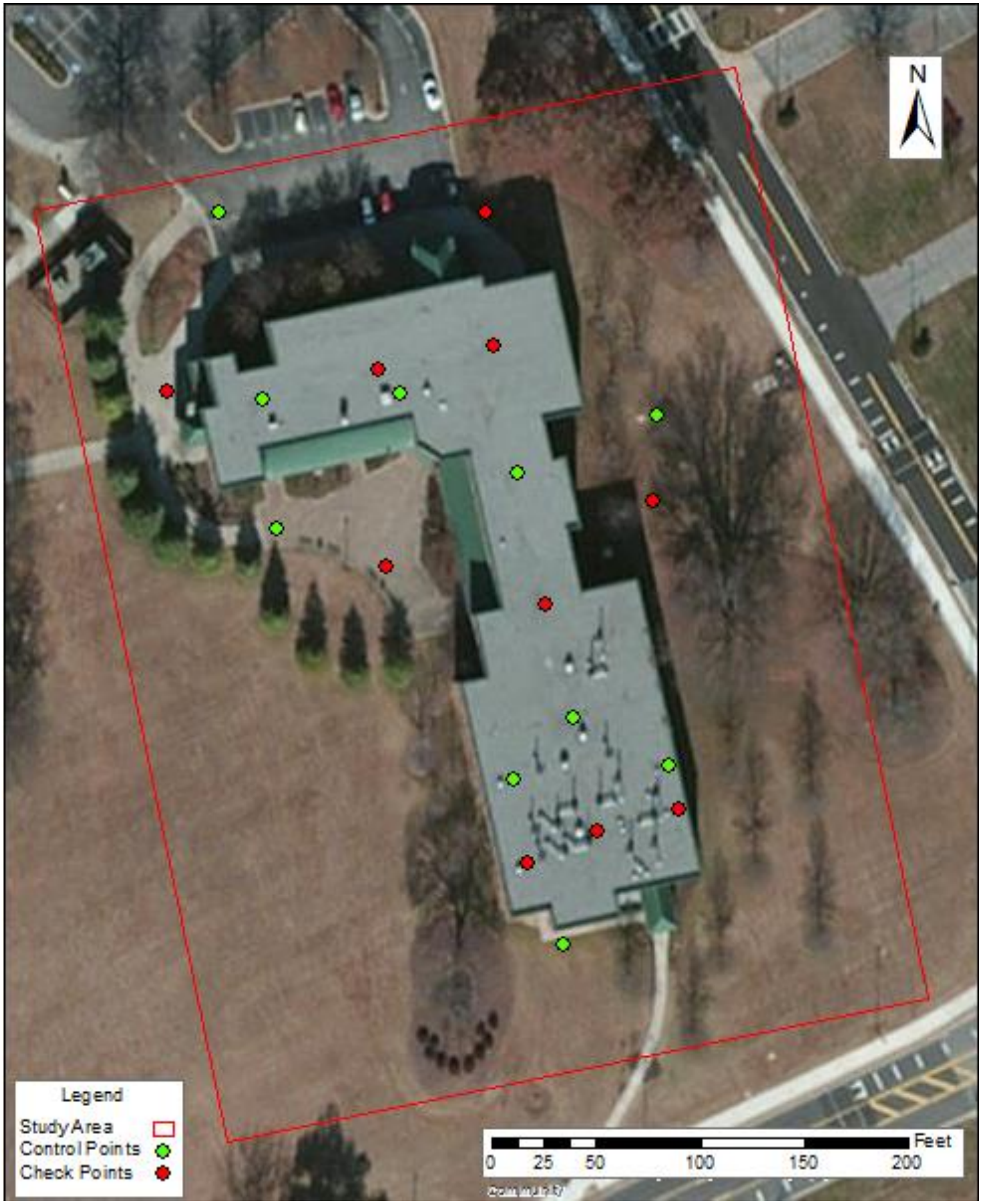


Figure 7. Locations of control points and check points that were collected for this project.

Mission Planning:

Neither drone was flown manually. For both, I planed a mission in their respective mission planning software packages, the missions were uploaded to the drones, and they flew themselves through raster patterns over the study area to collect all of the required imagery to achieve the mapping product that I was trying to generate. The eBee must use the included eMotion software to plan it's missions. Several options are available for the Inspire 1. For this study, I used Drone Deploy for the Inspire 1.

In both programs, the user simply draws a polygon around the area that they wish to be imaged, input the desired image resolution, and input the desired front and side lap of the image frames. For both drones, I set the same area to be imaged. I set both to collect 1 inch resolution imagery. Also, both were set for 80% front and side lap. The eBee flew at about 320 feet above the ground to achieve 1 inch imagery. Because the Inspire has a slightly higher resolution camera, it will flew a little bit lower at around 230 feet to achieve the same imagery resolution. Once the missions were planned and uploaded to the drones, eMotion and Drone Deploy become flight monitoring programs during the actual flights.

Imagery Collection:

Before each flight, I checked the weather, called the airport manager at the Gainesville airport, called campus security, and ensured that I had a visual observer to help me monitor the surrounding airspace. I am Part 107 Small UAS certified by the FAA so I was always the pilot in command. Per Part 107 regulations, I only flew during the day, when there was good visibility, remained under 400 ft above ground level, and remained within line of sight of the drones at all times. Remaining in line of sight of the drones was not difficult as the study area was not very large and there were not many trees or other vertical obstructions that blocked my line of sight. While each drone flew the imagery collection missions autonomously, both have controllers that allowed me to take manual control at any time that it was needed during an emergency.

Image Processing:

After the image collection flights, the imagery needed to be processed into orthoimages and digital surface models. I use Pix4D Mapper Pro software to accomplish this. The imagery was loaded into the software and the proper coordinate system was chosen for the outputs. I used NAD 1983 State Plane Georgia West (Feet) for this project. Next, the 9 control points were specified to the software. I manually input the coordinates for each control point, then selected it's location in at least 3 of the images from the drone flight. Precision selection was important in this step as variation in my selection of the location of the control points could have caused false differences in the two datasets. I used a license of Pix4D from the company that I work for and have it installed on my work laptop so this was the machine that I did the processing on. It is an I7 with 32GB of RAM. Even with this powerful machine, each flight will still took 3 to 4 hours to process.

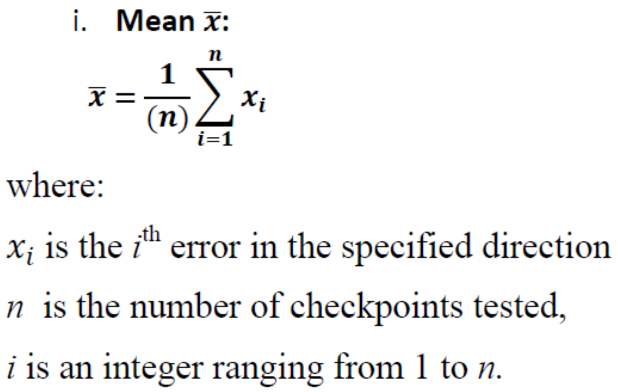
Error Measurement:

After processing the orthoimagery and digital elevation models in Pix4D for both flights, I imported the resulting rasters into ArcMap along with the point locations of the 8 check points collected within the study site. Next, the distance from the check point locations in the imagery and digital surface model to the point feature check points was measured in feet in x, y, and z dimensions. A root mean squared error was then calculated for the x, y, and z residuals for each drone's mapping products.

Analysis:

The most common method of analyzing positional accuracy is related to calculating the root mean squared error (RMSE) between accurately measured check points on the ground and the location of those check points in the final products as described above. The methodologies for the accuracy assessments in this project were drawn from Chapter 3: *Positional Accuracy* of *Assessing the Accuracy of Remotely Sensed Data* Congalton & Green (2009).

The RMSE was calculated for each direction of residuals (x, y, and z) for each drone's mapping products. To calculate the RMSE, first, the arithmetic mean of each direction of residuals is calculated: (see figure 8)



i. **Mean $\bar{x}$:**

$$\bar{x} = \frac{1}{(n)} \sum_{i=1}^{n} x_i$$

where:

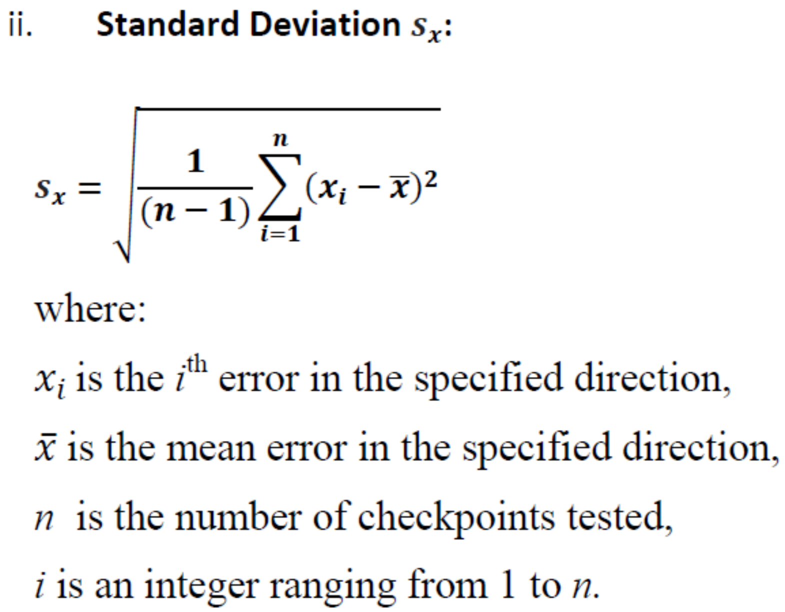
x_i is the i^{th} error in the specified direction

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Figure 8. Mean calculation (Abdullah, 2016)

Next, the means are used to calculate the standard deviation of each direction of residuals for each drone's mapping products: (see figure 9)



ii. **Standard Deviation s_x:**

$$s_x = \sqrt{\frac{1}{(n-1)}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

where:

x_i is the i^{th} error in the specified direction,

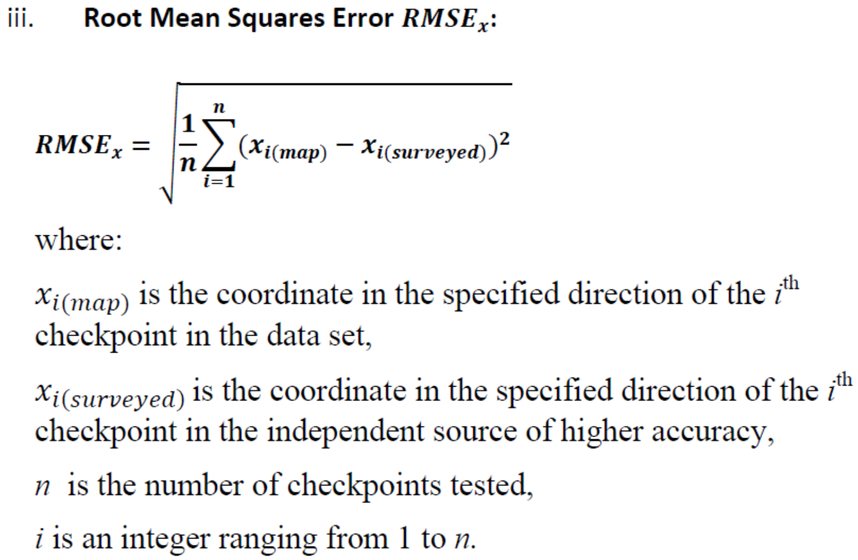
$\bar{x}$ is the mean error in the specified direction,

n is the number of checkpoints tested,

i is an integer ranging from 1 to n.

Figure 9. Standard Deviation Calculation (Abdullah, 2016)

Finally, the standard deviations are used to calculate the root mean squares error (RMSE) for each direction of residuals for each drone's mapping products: (see figure 10)



iii. **Root Mean Squares Error $RMSE_x$:**

$$RMSE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{i(map)} - x_{i(surveyed)})^2}$$

where:

$x_{i(map)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the data set,

$x_{i(surveyed)}$ is the coordinate in the specified direction of the i^{th} checkpoint in the independent source of higher accuracy,

n is the number of checkpoints tested,

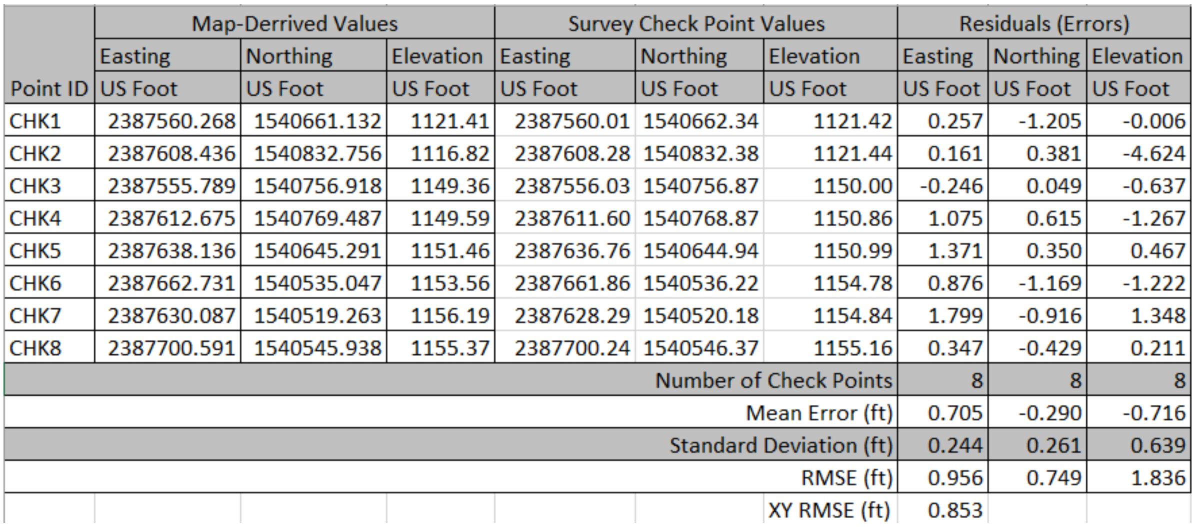
i is an integer ranging from 1 to n.

Figure 10. RMSE calculation (Abdullah, 2016)

Outcome:

As was expected, the mapping products that were generated from the eBee and the Inspire 1 had very similar resulting accuracies. Surprisingly, the Inspire 1 had a slightly better positional accuracy at 0.59 feet horizontal RMSE and 1.38 feet vertical RMSE than the eBee at 0.85 feet horizontal RMSE and 1.84 feet vertical RMSE. See tables 2 and 3 for all accuracy assessment results.

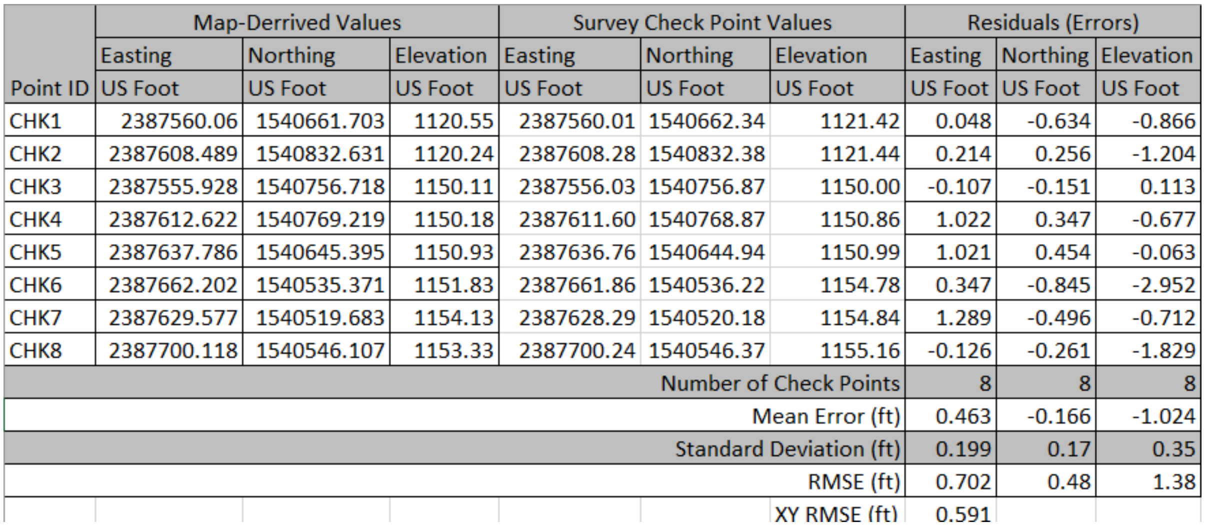
eBee Accuracy Assessment



	Map-Derrived Values			Survey Check Point Values			Residuals (Errors)		
	Easting	Northing	Elevation	Easting	Northing	Elevation	Easting	Northing	Elevation
Point ID	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot
CHK1	2387560.268	1540661.132	1121.41	2387560.01	1540662.34	1121.42	0.257	-1.205	-0.006
CHK2	2387608.436	1540832.756	1116.82	2387608.28	1540832.38	1121.44	0.161	0.381	-4.624
CHK3	2387555.789	1540756.918	1149.36	2387556.03	1540756.87	1150.00	-0.246	0.049	-0.637
CHK4	2387612.675	1540769.487	1149.59	2387611.60	1540768.87	1150.86	1.075	0.615	-1.267
CHK5	2387638.136	1540645.291	1151.46	2387636.76	1540644.94	1150.99	1.371	0.350	0.467
CHK6	2387662.731	1540535.047	1153.56	2387661.86	1540536.22	1154.78	0.876	-1.169	-1.222
CHK7	2387630.087	1540519.263	1156.19	2387628.29	1540520.18	1154.84	1.799	-0.916	1.348
CHK8	2387700.591	1540545.938	1155.37	2387700.24	1540546.37	1155.16	0.347	-0.429	0.211
						Number of Check Points	8	8	8
						Mean Error (ft)	0.705	-0.290	-0.716
						Standard Deviation (ft)	0.244	0.261	0.639
						RMSE (ft)	0.956	0.749	1.836
						XY RMSE (ft)	0.853		

Table 2. eBee Accuracy Assessment Results

Inspire 1 Accuracy Assessment



	Map-Derrived Values			Survey Check Point Values			Residuals (Errors)		
	Easting	Northing	Elevation	Easting	Northing	Elevation	Easting	Northing	Elevation
Point ID	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot	US Foot
CHK1	2387560.06	1540661.703	1120.55	2387560.01	1540662.34	1121.42	0.048	-0.634	-0.866
CHK2	2387608.489	1540832.631	1120.24	2387608.28	1540832.38	1121.44	0.214	0.256	-1.204
CHK3	2387555.928	1540756.718	1150.11	2387556.03	1540756.87	1150.00	-0.107	-0.151	0.113
CHK4	2387612.622	1540769.219	1150.18	2387611.60	1540768.87	1150.86	1.022	0.347	-0.677
CHK5	2387637.786	1540645.395	1150.93	2387636.76	1540644.94	1150.99	1.021	0.454	-0.063
CHK6	2387662.202	1540535.371	1151.83	2387661.86	1540536.22	1154.78	0.347	-0.845	-2.952
CHK7	2387629.577	1540519.683	1154.13	2387628.29	1540520.18	1154.84	1.289	-0.496	-0.712
CHK8	2387700.118	1540546.107	1153.33	2387700.24	1540546.37	1155.16	-0.126	-0.261	-1.829
						Number of Check Points	8	8	8
						Mean Error (ft)	0.463	-0.166	-1.024
						Standard Deviation (ft)	0.199	0.17	0.35
						RMSE (ft)	0.702	0.48	1.38
						XY RMSE (ft)	0.591		

Table 3. Inspire 1 Accuracy Assessment Results

Presentation Venue:

This project was presented at the 2017 GIS in the Rockies conference on September 21st to the Professional Land Survey tract. The conference was held in Denver, Colorado.

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