RPAS photogrammetry

P Barry MCInstCES and R Coakley, Baseline Surveys

How accurate is remotely piloted air system photogrammetry?

MUCH of current land, engineering and cadastral survey work using GNSS and total station is often labour intensive, sometimes involves surveyors working in hazardous environments and the completeness of the data captured often depends on the time allotted to the survey project. No representation of geography is perfect and certainly the point, text, line and polygon style of 21st century digital mapping is no exception. GNSS and total station geographic data collection methods are accurate enough to design civil engineering and architectural projects with sufficient practical accuracy (within ±5cm) to design roads, bridges, pipelines, buildings and so on. Although GNSS data is highly spatially accurate in both absolute and relative terms it completely falls down in richness of data. Each line, point and polygon must be described by textual means in order to communicate its geographic meaning. Its completeness is something we don't dare even to consider doubting, but there is an undeniable risk of a surveyor omitting data without even realising. This style of data collection is often time consuming and by nature expensive. As surveyors, we wanted to experiment with remotely piloted air system (RPAS) photogrammetry to see if it would be accurate enough to replace current GNSS and total station survey methods in engineering, cadastral and topographic surveys.

Revolution

This would revolutionise the world of engineering surveying in terms of vastly reducing data capture cost while vastly increasing data quality and richness. As we were practically pushing beyond the current accuracy limitation of RPAS-derived geographic data, we decided to use the C-Astral Bramor RPAS for its superior stability as an aerial data capture platform. Its stability being achieved by a combination of its aerodynamics and high end Lockheed Martin designed autopilot system. The high

> This would revolutionise the world of engineering surveying.

The C-Astral Bramor RPAS on the catapult ready for launch.

Ground control station and check point targets.

The stabilised Trimble GoeXR Network RTK GNSS used to get the coordinates of the target centres.

24MP precision of its Sony Nex-7 camera was another deciding factor along with its very clever safety feature of a remotely deployable parachute landing option. It also has 3-hour endurance and a practical wind tolerance of 20 knots when piloted by an experienced RPAS crew.

While we had decided on using network RTK GNSS to establish Irish Transverse Mercator coordinates on the centre positions of the ground control points, we carefully designed geometrically patterned ground markers which allowed us to obtain sub-pixel accuracy of the centre point location when identifying ground marker positions at the post data collection and pre-processing stage. Agisoft Photoscan was the software used for its stated accuracy 1-3 pixels and the high quality of the ortho photography and digital elevation model outputs. ArcMap was used for presenting the final fusion of data captured by RPAS and GNSS.

As surveyors we wanted to carry out our accuracy test in every day conditions which, by their very nature, are sub-optimal.

Simulation

The specific information we required was the actual accuracy that can be reliably achieved using an RPAS to collect data under field conditions throughout a typical 2Ha site. We flew an RPAS over the test area in a typical matrix pattern with an 80% front and 80% side overlap; we placed 45 ground markers as check points and surveyed them using network RTK GNSS. We specifically designed the ground markers to meet our accuracy needs. We established 10 separate control points and inputted these into our photo modelling software. The rest of the GNSS coordinated check marker data were added later in ArcMap to the completed orthomosaic and digital elevation model so we could accurately compare the RPAS photogrammetry XYZ data with the RTK GNSS XYZ data at highly reliable common points.

The accuracy we achieved throughout the 45 check points was 95% reliably within 41mm horizontally and 68mm vertically and with a 1cm ground sample distance. This finding has shown that XYZ data derived from RPAS photogrammetry has a similar practical accuracy to RTK GNSS, which is commonly used for cadastral, topographic and engineering survey work. This means that RPAS photogrammetry can replace GNSS surveying as the main method of data capture for engineering projects, boundary mapping and topographical surveying. Aerial photogrammetry can now be used for projects with a 1:200 map scale accuracy requirement.

Pre-flight planning

The nine ground control markers were theoretically positioned so that they were equidistantly distributed throughout the site to ensure an even distribution of errors. A flight plan was generated with an 80% overlap and an 80% sidelap and at an altitude of 90m to provide an expected GSD of 10mm. Flight direction was plotted at 90º to the actual wind direction so as to maintain a constant ground speed of less than 16m/s during the photographic process. This step helped to reduce ground smear, a phenomenon which blurs the pixels due to the movement of the RPAS.

Data acquisition system

The data acquisition system used on this project is a hybrid of Trimble GoeXR Network RTK GNSS and a C-Astral Bramor RPAS. We used the RTK GNSS to establish ITM coordinates on our specifically designed ground markers to provide photo control. The GNSS unit has a spatial accuracy in the region of 10-25mm both horizontally and vertically, due to the fact that we used struts to maintain steadiness during NRTK readings.

The C-Astral Bramor RPAS platform is a blended wing constructed of Kevlar and carbon fibre and has a 4kg MTOM. It is catapult launched, has extremely steady flight characteristics and advanced safety features afforded by its Lockheed Martin autopilot including a parachute deployment system for emergency and routine landing procedures. It carries a Sony Nex-7 24MP RGB sensor, which is oriented in portrait which allows for more forward overlap at a slower triggering interval. Our ground control markers were carefully designed so the most exact centre of the marker could be determined with a very high degree of accuracy from the photography at the processing stage.

The topography of the site had a 5m variation in level, was surrounded by mature woodland up to 25m in height and had numerous buildings.

On site conditions

As surveyors we wanted to carry out our accuracy test in every day conditions which, by their very nature, are sub-optimal. The prevailing weather conditions on the day of our flight test were cloudy with intermittent sunny spells with a wind speed at our flying altitude of 90m AGL was a maximum of 7m/s.

The detail of 1cm orthophotography can be seen here. This is a view looking down through the atrium over the dinning area of the surveyed hotel. Note the cutlery on the table.

Point No.	XY Error (m)	Z Error (m)	Point No.	XY Error (m)	Z Error (m)
1	0.025	0.06	24	0.008	0.02
2	0.023	0.02	25	0.000	0.03
3	0.014	0.01	26	0.004	-0.02
4	0.014	-0.04	27	0.012	0.03
5	0.018	-0.05	28	0.011	0.00
6	0.020	-0.02	29	0.029	0.02
7	0.035	-0.02	30	0.023	-0.05
8	0.019	-0.01	31	0.021	-0.04
9	0.010	0.04	32	0.010	-0.02
10	0.043	0.01	33	0.031	-0.07
11	0.041	0.04	34	0.007	-0.01
12	0.015	-0.01	35	0.026	-0.02
13	0.040	-0.01	36	0.040	-0.07
14	0.016	-0.02	37	0.007	-0.04
15	0.016	-0.02	38	0.012	-0.03
16	0.017	-0.03	39	0.007	-0.03
17	0.006	-0.02	40	0.025	0.02
18	0.047	-0.04	41	0.012	0.03
19	0.023	-0.02	42	0.033	0.03
20	0.008	0.05	43	0.024	0.07
21	0.010	0.00	44	0.015	0.01
22	0.013	-0.01	45	0.011	0.03
23	0.016	0.00			

Dataset of measured errors between the orthomosaic/DEM Network RTK GNSS for the target centres.

Label	X Error (m)	Y Error (m)	Z Error (m)	Error (m)	Projections	Error (pix)
Point 1	0.001958	0.001193	-0.000491	0.002344	33	1.277433
Point 10	0.009328	-0.026748	-0.012029	0.030776	9	0.883605
Point 2	0.000012	-0.003082	-0.024623	0.024815	35	1.419103
Point 3	-0.004135	0.010068	0.006249	0.012501	212	1.063595
Point 4	0.007812	0.009205	0.012708	0.017529	20	1.610777
Point 5	-0.000001	0.003609	0.007510	0.008332	18	0.551958
Point 6	-0.004106	-0.003277	0.012169	0.013255	19	0.574836
Point 7	-0.000441	-0.002176	-0.010497	0.010729	20	0.752000
Point 8	-0.002598	-0.004642	-0.006060	0.008064	16	0.845599
Point 9	-0.006739	0.000893	-0.016638	0.017973	18	0.610214

Control point errors.

The wind direction at altitude diverged from that used in our pre flight planning by 20º. This had the effect on the RPAS of getting a 10m/s variation in its ground speed when travelling with and against the wind. The topography of the site had a 5m variation in level, was surrounded by mature woodland up to 25m in height and had numerous buildings which would all contribute to turbulence at our flying altitude.

Data processing

Firstly 10 control stations and 45 check points, which were surveyed by Network RTK GNSS in Irenet95 coordinates, were

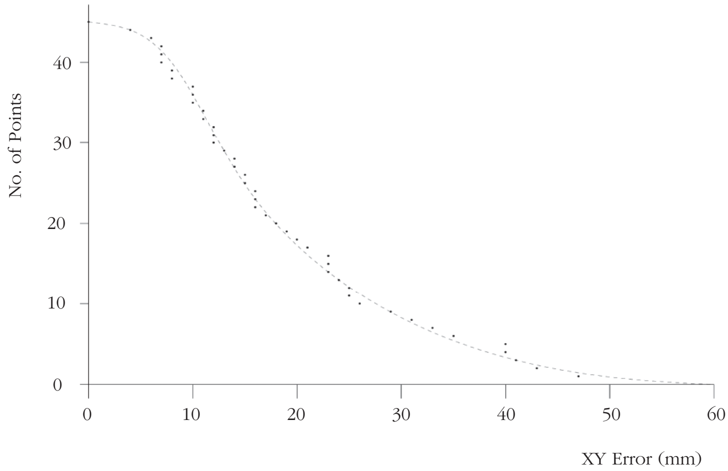
	XY (m)	Z (m)
Mean	0.021	0.031
RSME	0.023	0.035
Accuracy 95%	0.041	0.068

The mean, RSME and the accuracy derived from the figures in the table showing the dataset of measured errors. Accuracy at 95% confidence level is taken as planimetrically 1.7308 x RMSEr and vertically as 1.9600 x RMSEz. (Source: Geospatial Positioning Accuracy Standards. Part 3: National Standard for Spatial Data Accuracy).

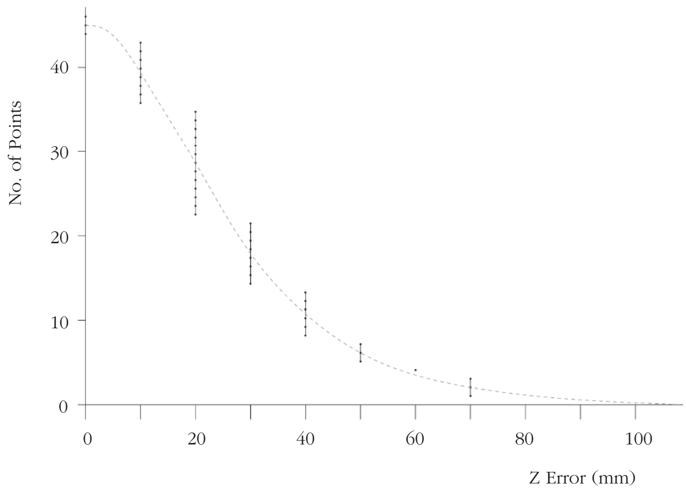
downloaded into Geosite office 5.1 and exported to AutoCADlt 2013 as two separate files. We downloaded 1,601 photographs from the Bramor RPAS along with the log file, which contains photo GNSS position, barometric height, roll, pitch and yaw. The photos and the logfile were then imported into Agisoft photoscan. The software eliminated superfluous photographs by deleting photos with high roll values, which occurred at turns. The refined 728 photographs were then used for the photo alignment stage; the reason why we used an oversized area is that we felt that the additional photographs would contribute to alignment accuracy of the target area. We then imported the 10 control stations into photoscan and identified the centre of each control point marker on each photo and attached it with its appropriate coordinate value. Of the 728 photographs we then used 168 photographs to further process the data into a 3D model for subsequent orthophoto and DEM output. The orthophoto was outputted at a resolution of 10.2mm pixel size and the DEM was outputted at 20mm GSD.

The resulting ITM geo-referenced orthophoto and DEM were imported into ArcGIS along with the GNSS CAD data. Distances were measured from the centre of the target, as they appeared on the orthophoto, to the centre of the target as measured by GNSS by using the ArcGIS measure tool to attain the distance between

The outputted orthomosaic.



The planimetric distribution of errors derived from the figures in the table showing the dataset of measured errors.



The distribution of vertical errors derived from the figures in the table showing the dataset of measured errors.

both readings. GNSS level point data were compared with DEM readings at the same point. Results were then recorded as highlighted in the image looking down through the atrium.

Distances were measured from the centre of the target, as they appeared on the orthophoto, to the centre of the target as measured by GNSS.

Results

The resulting geo-referenced orthophoto and DEM were imported into ArcMap along with the coordinated data from the RTK GNSS. (The difference between the two datasets is shown in the measured errors table.) The results where inputted to Microstation to produce the planimetric and vertical error graphs.

Discussion

The significance of the ability of a RPAS to capture geographic data at similar accuracies to RTK GNSS along with the richness of detail which can only be revealed by 10mm GSD aerial photography is truly revolutionary. Like all disruptive technologies, RPAS photogrammetry will take a couple of years to become mainstream, but when it does it will almost fully replace current methods of engineering surveying. The accuracy that can be achieved by RPAS photogrammetry is within 1:200 scales according to NSDI and FGDC mapping accuracy standards during sub-optimal conditions. Now that RPAS can be used to map at scales up to 1:200, they will start to take over from GNSS and total stations as the main survey grade data collection method as they are far more efficient at capturing geographic data, offering a huge financial advantage to government agencies and private companies using RPAS technology to collect geographic data, particularly over more detailed and larger sites.

Apart from an enormous time saving on data collection without an appreciable loss in accuracy, RPAS aerial photogrammetry offers far richer data than conventional survey vector data consisting of points, text and lines. Instead RPAS photogrammetry offers the user a bird's eye view of the site without any need for text or any fear of data being omitted. The accuracy to which levels are generated by the photogrammetry allows for contouring at 0.2m intervals which is very encouraging, GNSS readings would still be required for manhole covers, finished floor levels and so on, but even so, this still represents a huge leap forward in terms of surveying efficiency. In terms of representing the landscape, the orthophoto can be combined with the DEM to produce very accurate photorealistic 3D modelling in programmes such as ArcScene and can be analysed to yield highly accurate earthmoving volumetric calculations. This is the most spatially accurate aerial survey data that we could currently find anywhere on the internet.

P Barry MCInstCES, R Coakley, Baseline Surveys
Mount Desert Lodge, Lee Road, Cork, Co. Cork Ireland
paudie@baselinesurveys.ie www.baselinesurveys.ie

References

Eisenbeiss H., 2004. RPAS Photogrammetry. www.igp-data.ethz.ch/berichte/blaue_Berichte_PDF/105.pdf. [accessed 03 April 2013].
Niranjan et al., 2007. Initial Efforts toward Mission-Specific Imaging Surveys from Aerial Exploring Platforms: RPAS. www.gisdevelopment.net/proceedings/mapworldforum/poster/MWF_Poster_127.pdf. [accessed 06 April 2013].
Bendea et al., 2007. Mapping of Archeological Areas using a Low Cost RPAS. www.isprs.org/proceedings/XXXVI/5-C53/papers/FP025.pdf. [accessed 06 April 2013].
Puschel H., 2009. Set up of a Photogrammetric test field for RPAS-Platforms. www.igp.ethz.ch/photogrammetry/.../RPAS_Testfield_klein.pdf. [accessed 07 April 2013].
Vallet et al., 2011. Photogrammetric Performance of an Ultra Light Weight Swinglet RPAS. www.isprs.org/proceedings/XXXVIII/1-C22/papers/vallet.pdf. [accessed 7 April 2013].
Rock et al., 2011. Sensitivity Analysis of RPAS_Photogrammetry for Creating Digital Elevation Models (DEM). www.geometh.ethz.ch/auv_g/rock_presentation. [accessed 08 April 2013].
Haala et al., 2011. Performance Test on RPAS-BasedPhotogrammetric Data Collection. www.isprs.org/proceedings/XXXVIII/1-C22/papers/haala.pdf. [accessed 9 April 2013].
Kung et a., 2011. The Accuracy of Automatic Photogrammetric Techniques on Ultra-Light RPAS Imagery. www.isprs.org/proceedings/XXXVIII/1-C22/papers/strecha.pdf. [accessed 9 April 2013].
The American Society for Photogrammetry and Remote Sensing, 1990.
ASPRS Accuracy Standards for Large-scale Maps.
Subcommittee for Base Cartographic Data Federal Geographic Data Committee, 1996. Geospatial Positioning Accuracy Standards.
Part 3: National Standard for Spatial Data Accuracy.

The (CES) social network

A stark reminder of the importance of H&S – 148 people didn't go home from work last year bit.ly/12GciLx #fatalitystats2013
@H_S_E

We've decided to switch from 2D to Open BIM. Now what? What's the general process of immersing an MEP firm into BIM implementation? How did your company ease into it?
BIM Experts

Some of the 5,500 trig pillars still standing around Great Britain are the focus of a photography exhibition ow.ly/md490
@OrdnanceSurvey

It's #maizemaze2013 marking out time ! Hitech GPS satellite navigation giant dot to dot!
@redhousefarm

How to deal with weather events in the TSC I understand that there is no allowance for a compensation event due to a weather event in the Term Service Contract. What is the mechanism for dealing with a weather event that has prevented the contractor from undertaking any work on the contract?
NEC Contracts Official Group

Daddy and his '3D Camera' by James Straughan age 4 #laserscanning pic.twitter.com/wFNumbC0i1
@david_straughan

Sunny day at last - and where's Scott? An underground car park in central #London. Mike however is outside in the sun.
#benefitsofmanagement
@RLSurveys

Ordnance Survey features on CBBC's Blue Peter. Find out more: http://bit.ly/12omCc5
Ordnance Survey

Well, that took all of 5 minutes: Photoshop And Whole Creative Cloud Already Cracked And Pirated cultofmac.com/?p=232682
@GeraldKelley

Would you like to read new RICS President Michael Newey's inaugural speech? Here's a snippet: "In many ways, I am but the 132nd runner to carry the baton in a relay race that has lasted 145 years..."
RICS