Accuracy Assessment for points coordinates surveyed using low-cost Unmanned Aerial Vehicle and Global Positioning System with 3Dsurvey and 3DF Zephyr software

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Abstract. Ground Control Points GCPs are the only way to obtain accurate positions in aerial surveys. At least three points should be utilized, and the model will get increasingly accurate in X, Y, and Z coordinates as the number rises. The accuracy of the 3D model created from aerial photography is also affected by the arrangement of GCPs. The goal of this research is to determine the optimal number and arrangement of GCPs in order to obtain the lowest possible error in point positioning. A conventional UAV called DJI Mavic 2 pro was used to photograph one and a half square kilometer site at an elevation equal to hundred meters from earth’s surface with nadir camera configuration. GSD (ground sampling distance) of 2.3 centimeters was used to collect 1515 pictures. 62 GCPs were observed in PPK (Post Processing kinematic) method using a DGPS (differential global positioning system) receiver GS 15 from Leica. The study area was split into two areas, one with a straight arrangement of GCPs and the other with a diagonal arrangement of GCPs. The pictures were processed using 3Dsurvey and 3DF Zephyr software utilizing a full bundle adjustment procedure with increasing GCPs number beginning with three GCPs and ending with twenty-six GCPs for both arrangement layout, with the other points serving as check points for the model’s accuracy at each attempt. The check point coordinates obtained were compared to the DGPS coordinates. The result indicates the optimal GCP number needed for the most accurate position and spread layout. That the minimum gap between adjacent GCPs ought to be not over than 100 meters and spread homogenously.

1. Introduction
Unmanned aerial vehicles stereo photography has lately got a lot of interest in engineering fields such as surveying and mapping, environment monitoring, and Geographical Information System (GIS) [1,2]. Stereo photography plays a prominent part in generating three - dimensional models for multiple sites and features using three-Dimensional photogrammetry [3,4]. Take advantage of its accessibility, affordability, portability, and simplicity of usage. Researchers from all around the world have begun to investigate the capabilities and benefits which these systems provide, and many breakthroughs have been achieved in this area. One of its major issues with using unmanned aerial vehicles mapping systems would be that they need GCPs to attain highly accurate results [5,6] concerning the locations of the sites and features getting surveyed, allowing people to obtain highly precise measurements on the results of these systems, including orthomosics [7,8], 3-dimensional point clouds, and digital surface models [9]. Ground control points are utilized to link the project to a well-known reference system to ensure getting precise measurements [10]. The arrangement and amount of these control points have a significant impact on the accuracy of the results. The accuracy of the resulting model will improve as the number
of GCPs is increased [11]. The model’s accuracy is also affected by how the GCPs are dispersed across the project [12]. The optimal number of GCPs for UAV mapping systems is the subject of considerable study [13,14]. Oniga et al. looked into the best amount of GCPs for UAS images, however they didn’t examine the impact of point arrangement on the project's end outcomes, and their research was restricted to a limited region [16-18].

This research seeks to find the optimum amount and arrangement of ground control points for producing precise three-dimensional model from a conventional UAV photography system, that has an impact on results like orthomosaic and DSM. The ground control points surveyed with millimeter accuracy using post processing kinematic approach and used to rectify 1515 overlapping nadiral photographs collected at hundred meters from the ground. The ground control points were laid out in a diagonal arrangement from the start point of the project till the third kilometer and in straight arrangement for the remainder distance of the study area. The pictures were processed using two distinct software solutions: 3Dsurvey program and 3DF zephyr software. By checking the produced coordinates of the ground control points with the actual coordinates obtained by GPS, the project’s precision was evaluated.

In this research, a DJI Mavic 2 Pro UAV was used to photograph a 1.5 km2 region at 100 meters above ground level with 2.3-centimeter GSD, and 62 ground control points were surveyed using a GS15 GPS receiver from Leica and dispersed in a straight and diagonal arrangement.

2. Area of the Study

Unmanned aerial The study area has been the initial 6 km of Qanat Al-Jaish Project, a 25-kilometer canal that connects the Tigris River in Baghdad, Iraq, to Diyala River in the south. Research area is a longitudinal region with an approximate width of 250 meters and a length of 6.15 kilometers that includes the canal and two gardens and highways on each bank. (See Figure 1).

![Figure 1: Area of study (Qanat Al-Jaish) with GCPs arrangement overlayed over street map.](image-url)
3. Materials and methodology

3.1. Ground Control Points Observation

Observation of the geographic coordinates of GCPs is critical for obtaining exact positions, and all these GCPs must have a minor error to produce extremely accurate measurements. Through using Post Processing Kinematic PPK method, GS15 GPS receiver from Leica has been employed to determine the geographic locations of the ground control points in this research. The base station has been employed to measure one of the ground control points in the middle of the site. The duration of measurement was 15 and a half hours. The remaining GCPs have been observed using the rover receiver, for each GCP having a 15-minute observation duration. A red dot approximately 15 cm in diameter and a center white dot around 5 cm in diameter were placed on each GCP. After 2 weeks, the data from the base station is processed using the OPUS website with an RMSE (Root Mean Square Error) of 1.5 millimeter in easting, 2 millimeters in northing, and 2 millimeters in elevation. The remaining GCPs then processed by LGO (leica geo office) program using the base station as a reference. These GCPs had an average RMS error of 1.8 millimeters in the easting coordinate, 1.3 millimeters in the northing coordinate, and 2 millimeters in the elevation coordinate. The site includes sixty-two ground control point that are placed in two ways along the canal route. The GCPs are spread in straight arrangement throughout the first 3 kilometers of the site, with two aligned stations each 100 meters along the waterway's route. The GCPs throughout the site’s second 3 km are placed in a diagonal arrangement, with one station on one bank of the canal and the next station on the opposite bank separated by approximately 100 meters. (See figure 2, figure 3 and Table 1).

![Figure 2. GCPs Straight arrangement.](image1)

![Figure 3. GCPs Diagonal arrangement.](image2)
| ID   | Easting   | Northing   | elevation  | $H.$ accuracy | $V.$ accuracy |
|------|-----------|------------|------------|---------------|---------------|
| CP1  | 441624.012| 3696436.067| 33.820     | 0.002         | 0.002         |
| CP2  | 441499.742| 3696579.676| 33.790     | 0.002         | 0.002         |
| CP3  | 441337.032| 3696723.992| 33.945     | 0.002         | 0.002         |
| CP4  | 441219.819| 3696837.562| 34.078     | 0.002         | 0.002         |
| CP5  | 441076.532| 3696973.791| 33.749     | 0.002         | 0.002         |
| CP6  | 440927.269| 3697125.457| 34.429     | 0.002         | 0.002         |
| CP7  | 440788.923| 3697269.073| 33.885     | 0.002         | 0.002         |
| CP8  | 440613.337| 3697403.059| 34.440     | 0.002         | 0.002         |
| CP9  | 440489.193| 3697552.708| 33.885     | 0.002         | 0.002         |
| CP10 | 440341.834| 3697679.175| 34.065     | 0.002         | 0.002         |
| CP11 | 440189.004| 3697807.793| 34.082     | 0.002         | 0.002         |
| CP12 | 440036.013| 3697956.317| 34.178     | 0.002         | 0.002         |
| CP13 | 439854.053| 3698124.450| 34.181     | 0.002         | 0.002         |
| CP14 | 439722.983| 3698268.974| 34.293     | 0.002         | 0.002         |
| CP15 | 439543.036| 3698401.204| 34.439     | 0.002         | 0.002         |
| CP16 | 439409.246| 3698550.699| 34.397     | 0.002         | 0.002         |
| CP17 | 439421.088| 3698572.633| 35.470     | 0.002         | 0.002         |
| CP18 | 439612.733| 3698440.535| 34.219     | 0.002         | 0.002         |
| CP19 | 439746.433| 3698284.272| 34.152     | 0.002         | 0.002         |
| CP20 | 439884.093| 3698186.924| 34.107     | 0.002         | 0.002         |
| CP21 | 440084.315| 3697991.637| 34.021     | 0.002         | 0.002         |
| CP22 | 440247.204| 3697854.218| 33.988     | 0.002         | 0.002         |
| CP23 | 440392.864| 3697685.668| 33.953     | 0.002         | 0.002         |
| CP24 | 440530.325| 3697543.033| 33.920     | 0.002         | 0.002         |
| CP25 | 440660.219| 3697419.899| 33.904     | 0.002         | 0.002         |
| CP26 | 440807.077| 3697280.895| 33.913     | 0.002         | 0.002         |
| CP27 | 440950.327| 3697144.190| 33.903     | 0.002         | 0.002         |
| CP28 | 441119.975| 3697003.668| 33.879     | 0.002         | 0.002         |
| CP29 | 441267.142| 3696852.271| 33.865     | 0.002         | 0.002         |
| CP30 | 441370.749| 3696794.723| 34.124     | 0.002         | 0.002         |
| CP31 | 441450.261| 3696702.129| 33.984     | 0.002         | 0.002         |
| CP32 | 441617.426| 3696547.355| 33.852     | 0.002         | 0.002         |
| CP33 | 441772.779| 3696406.545| 33.740     | 0.002         | 0.002         |
| CP34 | 441916.366| 3696245.648| 33.727     | 0.002         | 0.002         |
| CP35 | 442096.706| 3696103.673| 33.606     | 0.002         | 0.002         |
| CP36 | 442220.465| 3695949.971| 33.650     | 0.002         | 0.002         |
| CP37 | 442410.687| 3695799.330| 33.611     | 0.002         | 0.002         |
| CP38 | 442551.441| 3695665.484| 33.638     | 0.002         | 0.002         |
| CP39 | 442702.216| 3695524.204| 33.548     | 0.002         | 0.002         |
| CP40 | 442839.724| 3695396.032| 33.570     | 0.002         | 0.002         |
| CP41 | 443003.134| 3695214.442| 33.277     | 0.002         | 0.002         |
| CP42 | 443157.238| 3695078.230| 33.491     | 0.002         | 0.002         |
3.2. Data Capturing

DJI’s Mavic 2 Pro UAV was used to photograph the site. The UAV features an integrated camera with a sensor width and height of 13.2 millimeter and 8.8 millimeter respectively, with 5472 pixels and 3648 pixels image wide and height respectively. DJI Pilot program is used to plan the flight, which has a Linear Flight Mission option with identical right and left distances of 250 meters and a band length of 2 kilometers. On a single grid, 9 bands must be fully surveyed with 80% side overlapping and a 70% frontal overlapping for the study area. All of the photographs were shot at nadir, at a height of 100 meters above the earth. A total of 1515 photographs were used to photograph the 1.5 km² project, with an averaged ground sampling distance of 2.3 cm. (see figure 4 and figure 5).

| CP  | X Coord. | Y Coord. | X Accuracy | Y Accuracy |
|-----|----------|----------|------------|------------|
| CP43 | 443302.011 | 3694964.701 | 33.525 | 0.002 | 0.002 |
| CP44 | 443439.023 | 3694826.246 | 33.479 | 0.002 | 0.002 |
| CP45 | 443599.351 | 3694677.756 | 33.406 | 0.002 | 0.002 |
| CP46 | 443724.268 | 3694534.313 | 33.433 | 0.002 | 0.002 |
| CP49 | 443621.908 | 3694566.320 | 33.499 | 0.002 | 0.002 |
| CP50 | 443458.404 | 3694729.955 | 33.487 | 0.002 | 0.002 |
| CP51 | 443313.206 | 3694862.691 | 33.423 | 0.002 | 0.002 |
| CP52 | 443190.297 | 3695006.894 | 33.483 | 0.002 | 0.002 |
| CP53 | 443010.374 | 3695175.422 | 33.114 | 0.002 | 0.002 |
| CP54 | 442897.219 | 3695283.423 | 33.542 | 0.002 | 0.002 |
| CP55 | 442728.501 | 3695429.459 | 33.601 | 0.002 | 0.002 |
| CP56 | 442589.293 | 3695555.928 | 33.595 | 0.002 | 0.002 |
| CP57 | 442460.833 | 3695670.177 | 33.668 | 0.002 | 0.002 |
| CP58 | 442309.198 | 3695836.331 | 33.708 | 0.002 | 0.002 |
| CP59 | 442129.595 | 3696007.461 | 33.739 | 0.002 | 0.002 |
| CP60 | 441985.663 | 3696138.304 | 33.706 | 0.002 | 0.002 |
| CP61 | 441787.566 | 3696311.107 | 33.777 | 0.002 | 0.002 |
| CP62 | 441640.122 | 3696428.409 | 33.715 | 0.002 | 0.002 |

Table 1: ground control points GPS coordinates and their accuracy

Figure 4. mission planning using DJI Pilot application for android.

Figure 5. DJI Mavic 2 pro.
3.3. Processing of the Data

Processing of the data was carried out by two distinct programs in order to get a basic understanding about how each operates and which one is superior. The region is divided into two sections in both software: one is for straight GCP arrangement, that has 31 GCPs, and the other one for diagonal GCP arrangement, that has 31 GCPs as well. The model is processed with an increasing amount of Ground control points, beginning with just three GCPs, the remaining twenty-eight marks serving as check points, and finishing with 26 GCPs and 5 check points. The Root Mean Square error of the check points, which describes the distance between check points estimated coordinates from the program and their actual coordinates observed using DGPS, was used to indicate the model's accuracy.

3.3.1. Using 3Dsurvey software to process the data

3Dsurvey software processing is done in a series of stages. For each processing stage, the user may choose his own preferences and settings. The user must first establish a new project before importing the pictures that make up the survey model into the program. In our instance, we used the program to import 1515 pictures for the whole project. Each picture has a geotag attached to it, which allows the program to determine the starting location and orientation of the preceptive center of the camera, although these locations aren't very accurate. After importing the pictures, you must choose the coordinate system used to measure the camera perspective center’s coordinate and its precision. In our instance, the horizontal coordinate system is WGS 1984 UTM zone 38N, while the vertical Datum is EGM 2008. The same coordinate system is used for both the input and output coordinate systems. Because we have to create a three-dimensional model, we selected 3D map from the processing choices, that is a predefined set of options for various processing styles. Geometrically validated matching utilized as the project's matching technique to begin the picture matching process. The program will be able to compute the inside sensor parameters. The GCPs imported to the project as csv files from the Ground Control Points Manager after executing the initial processing phase for first time, for each point's vertical and horizontal precision equal to 2 millimeters. Every GCP will be meticulously annotated on the photos in order to link the model to a precise location, these ground control points will be modified to either CK (Check Point) or CP (Control Point). After that, we reoptimize the project to recalculate tie point positions in relation to the ground control points added lately. For each trial, a report produced for the first processing step and kept in order to perform a comparison to the Root Mean Square error for each number of ground control point and Checkpoints employed. (See figure 6).

Figure 6: 3Dsurvey software
3.3.2. Using 3DF Zephyr to process the data
With minor workflow changes, the 3DF Zephyr conducts processing almost identically to the 3Dsurvey. The processing starts with the creation of a new project and the importation of photos from the menu, that includes the necessary processing stages. We began aligning the photos and generating initial points that represents the model through picking align photos out from the menu as well as picking high for precision. The thresholds for the critical point and tie point were established at forty thousand and ten thousand, that will lead to align the perspective center in a manner comparable to the travel route, resulting in the model's three-dimensional tie points. Following that, ground control points are inserted into the project as csv format, each with a unique coordinate, the precision of the points set to two millimeters. The method of picking Ground control points on the photos is identical to how the 3Dsurvey program works, every point being meticulously picked on a minimum of five photographs. The final step in referencing is to optimize cameras to the recently added GCPs, choose point kind (check or control point), then reoptimize the project for each iteration of control to check point utilized. A report of the processing outcome is produced and stored for comparing for each repetition.

![3DF Zephyr software](image)

Figure 7: 3DF Zephyr software

4. Results
4.1. Results for Straight arrangement
While 3Dsurvey software has been utilized to conduct full bundle adjustment to the model, the root mean square error is 5.091 meter when the minimum number of Ground control points has been used, and that was three ground control points, and computed out from the other twenty eight check points, whereas the full number of Ground control points, that was 26 GCPs, did result in a root mean square of 0.046 m measured out from the other 5 check points, but the root mean square was quickly reduced to 0.268 m after having added 7 more GCPs As 15 GCPs are employed to reference the model, the root mean square decreases to under 10 cm. As we bring extra GCPs, the quantity of root mean square reduces, but the variance between successive trials diminishes as well, until it reaches approximately two to five millimetres (See table 2 and chart 1).
As we used 3DF Zephyr program to adjust the bundle, a 5.704-meter RMSE was obtained by employing the smallest number of GCPs, three ground control points, and measuring the other twenty-eight check points. RMSE for the last 5 check points was 0.049 m when the maximum number of ground control points were used, which was 26. The RMSE was reduced to 0.294 m with the addition of seven additional GCPs, bringing the total number of GCPs to ten. While fifteen ground control points are obtained to reference the model, the RMSE is less than 10 cm after adding additional GCPs. As we add additional GCPs, the quantity of RMSE reduces, but the variance between successive trials diminishes as well, until it reaches approximately four to eight millimetres. (See table 2 and chart 2).

| No. of GCPs | No. of CKPs | 3Dsurvey X | 3Dsurvey Y | 3Dsurvey Z | RMSE | 3DF Zephyr X | 3DF Zephyr Y | 3DF Zephyr Z | RMSE | RMSE diff. |
|-------------|-------------|------------|------------|------------|------|-------------|-------------|-------------|------|------------|
| 3           | 28          | 2.235      | 2.538      | 3.806      | 5.091| 2.048       | 2.158       | 4.866       | 5.704| -0.612     |
| 4           | 27          | 1.828      | 2.142      | 3.205      | 4.267| 1.455       | 1.66        | 3           | 3.725| 0.541      |
| 5           | 26          | 1.426      | 1.261      | 1.581      | 2.475| 1.068       | 0.957       | 1.462       | 2.048| 0.427      |
| 6           | 25          | 0.962      | 0.822      | 1.043      | 1.639| 0.857       | 0.752       | 0.949       | 1.484| 0.156      |
| 7           | 24          | 0.499      | 0.512      | 0.877      | 1.131| 0.625       | 0.55        | 0.8         | 1.155| -0.023     |
| 8           | 23          | 0.327      | 0.32       | 0.716      | 0.85 | 0.566       | 0.275       | 0.704       | 0.944| -0.094     |
| 9           | 22          | 0.305      | 0.314      | 0.663      | 0.794| 0.29        | 0.195       | 0.647       | 0.736| 0.059      |
| 10          | 21          | 0.234      | 0.261      | 0.529      | 0.635| 0.199       | 0.174       | 0.415       | 0.492| 0.143      |
| 11          | 20          | 0.216      | 0.245      | 0.45       | 0.556| 0.18        | 0.168       | 0.381       | 0.454| 0.102      |
| 12          | 19          | 0.191      | 0.185      | 0.372      | 0.457| 0.155       | 0.15        | 0.294       | 0.365| 0.093      |
| 13          | 18          | 0.156      | 0.165      | 0.321      | 0.393| 0.135       | 0.14        | 0.274       | 0.336| 0.058      |
| 14          | 17          | 0.122      | 0.153      | 0.263      | 0.328| 0.136       | 0.14        | 0.255       | 0.321| 0.006      |
| 15          | 16          | 0.086      | 0.101      | 0.233      | 0.268| 0.128       | 0.119       | 0.236       | 0.294| -0.026     |
| 16          | 15          | 0.066      | 0.092      | 0.217      | 0.244| 0.095       | 0.099       | 0.191       | 0.236| 0.009      |
| 17          | 14          | 0.064      | 0.073      | 0.19       | 0.213| 0.073       | 0.081       | 0.18        | 0.21 | 0.003      |
| 18          | 13          | 0.061      | 0.065      | 0.165      | 0.188| 0.061       | 0.064       | 0.146       | 0.17 | 0.017      |
| 19          | 12          | 0.045      | 0.05       | 0.128      | 0.144| 0.047       | 0.043       | 0.134       | 0.149| -0.004     |
| 20          | 11          | 0.042      | 0.036      | 0.095      | 0.11 | 0.04        | 0.039       | 0.122       | 0.134| -0.024     |
| 21          | 10          | 0.037      | 0.033      | 0.074      | 0.089| 0.04        | 0.037       | 0.101       | 0.115| -0.026     |
| 22          | 9           | 0.04       | 0.035      | 0.064      | 0.083| 0.037       | 0.035       | 0.087       | 0.101| -0.018     |
| 23          | 8           | 0.038      | 0.028      | 0.055      | 0.072| 0.035       | 0.032       | 0.056       | 0.074| -0.002     |
| 24          | 7           | 0.035      | 0.025      | 0.048      | 0.065| 0.029       | 0.027       | 0.044       | 0.059| 0.006      |
| 25          | 6           | 0.028      | 0.021      | 0.043      | 0.055| 0.027       | 0.022       | 0.039       | 0.053| 0.003      |
| 26          | 5           | 0.025      | 0.017      | 0.035      | 0.046| 0.026       | 0.019       | 0.037       | 0.049| -0.003     |

Table 2. processing results for bundle adjustment for straight ground control point arrangement using 3Dsurvey and 3DF Zephyr program.
4.2. Results for diagonal arrangement
While 3Dsurvey program was used to conduct adjustment for the project, the root mean square error was 2.919 m while the minimum number of Ground control points has been used, that was three ground control points, and computed out from the other twenty eight check points, whereas the highest number of Ground control points, that was 26 GCPs, did result in an root mean square error of 0.036 m measured out from the other 5 check points, but the root mean square error was quickly reduced to 0.221 m after assigning 7 more GCPs As 15 GCPs are utilized to reference the model, the root mean square error falls below 10 cm. When we add additional Ground control points, the quantity of root mean square error reduces, but the variance between successive trials also reduces until it reaches approximately two to five millimeters. (See table 3 and chart 3).

**Chart 1.** Straight ground control point arrangement results using 3Dsurvey.

**Chart 2.** Straight ground control point arrangement results using 3DF Zephyr.
When using 3DF Zephyr program to adjust the bundle, a 3.674 meter RMSE was obtained by employing the smallest number of GCPs, three ground control points, and measuring the other twenty eight check points. The RMSE for the last 5 check points was 0.041 m while the maximum number of ground control points used, which was 26. The RMSE was reduced to 0.688 m with the addition of seven additional GCPs, bringing the total number of GCPs to ten. When 19 GCPs are obtained to reference the model, the RMSE is less than 10 cm after adding additional GCPs. As we add additional GCPs, the quantity of RMSE reduces, but the variance between successive trials diminishes as well, until it reaches approximately four to eight millimeters. (See table 3 and chart 4).

| No. of GCPs | No. of CKPs | 3Dsurvey | 3DF Zephyr | RMSE diff. |
|-------------|-------------|----------|------------|------------|
|             |             | X        | Y          | Z          | X        | Y          | Z          |            |
| 3           | 28          | 1.456    | 1.17       | 2.243      | 2.919    | 1.965      | 1.548      | 2.691      | 3.674      | -0.755     |
| 4           | 27          | 1.204    | 0.943      | 1.264      | 1.984    | 1.052      | 1.068      | 1.571      | 2.172      | -0.187     |
| 5           | 26          | 0.945    | 0.676      | 1.031      | 1.554    | 0.918      | 0.927      | 0.993      | 1.64       | -0.086     |
| 6           | 25          | 0.748    | 0.381      | 0.888      | 1.222    | 0.82       | 0.656      | 0.884      | 1.373      | -0.151     |
| 7           | 24          | 0.536    | 0.304      | 0.819      | 1.025    | 0.539      | 0.557      | 0.805      | 1.118      | -0.093     |
| 8           | 23          | 0.429    | 0.286      | 0.574      | 0.772    | 0.39       | 0.483      | 0.74       | 0.966      | -0.194     |
| 9           | 22          | 0.257    | 0.249      | 0.546      | 0.653    | 0.277      | 0.357      | 0.691      | 0.826      | -0.173     |
| 10          | 21          | 0.166    | 0.192      | 0.443      | 0.511    | 0.189      | 0.314      | 0.583      | 0.688      | -0.178     |
| 11          | 20          | 0.121    | 0.184      | 0.408      | 0.463    | 0.176      | 0.221      | 0.461      | 0.541      | -0.078     |
| 12          | 19          | 0.094    | 0.146      | 0.373      | 0.411    | 0.121      | 0.165      | 0.389      | 0.44       | -0.028     |
| 13          | 18          | 0.084    | 0.106      | 0.293      | 0.323    | 0.098      | 0.139      | 0.306      | 0.35       | -0.027     |
| 14          | 17          | 0.073    | 0.094      | 0.254      | 0.28     | 0.089      | 0.111      | 0.248      | 0.286      | -0.005     |
| 15          | 16          | 0.067    | 0.086      | 0.192      | 0.221    | 0.07       | 0.081      | 0.202      | 0.229      | -0.008     |
| 16          | 15          | 0.051    | 0.073      | 0.17       | 0.192    | 0.054      | 0.075      | 0.198      | 0.218      | -0.027     |
| 17          | 14          | 0.03     | 0.06       | 0.138      | 0.154    | 0.04       | 0.059      | 0.176      | 0.19       | -0.036     |
| 18          | 13          | 0.026    | 0.052      | 0.084      | 0.102    | 0.033      | 0.039      | 0.097      | 0.11       | -0.008     |
| 19          | 12          | 0.025    | 0.03       | 0.073      | 0.083    | 0.03       | 0.035      | 0.083      | 0.095      | -0.012     |
| 20          | 11          | 0.022    | 0.027      | 0.063      | 0.072    | 0.028      | 0.032      | 0.056      | 0.07       | 0.0013     |
| 21          | 10          | 0.021    | 0.027      | 0.05       | 0.061    | 0.024      | 0.03       | 0.048      | 0.062      | -0.001     |
| 22          | 9           | 0.02     | 0.025      | 0.048      | 0.057    | 0.021      | 0.022      | 0.039      | 0.049      | 0.0083     |
| 23          | 8           | 0.018    | 0.022      | 0.036      | 0.046    | 0.017      | 0.019      | 0.036      | 0.044      | 0.0019     |
| 24          | 7           | 0.014    | 0.016      | 0.033      | 0.039    | 0.014      | 0.022      | 0.035      | 0.044      | -0.005     |
| 25          | 6           | 0.012    | 0.016      | 0.032      | 0.038    | 0.016      | 0.021      | 0.034      | 0.043      | -0.005     |
| 26          | 5           | 0.012    | 0.015      | 0.031      | 0.036    | 0.015      | 0.021      | 0.032      | 0.041      | -0.005     |

Table 3. processing results for bundle adjustment for diagonal ground control point arrangement using 3Dsurvey and 3DF Zephyr program.
Discussion

The data obtained from each project’s bundle adjustment provides an idea of different variables influence the precision of point cloud positions. Because this is a longitudinal project, the referencing procedure differs from that of a wide-area project. Because the area varies quickly at long directions compared to short ones, ground control points must be arranged in such manner where the additional area is covered. The two configurations chosen are the most reasonable ones for ensuring complete coverage of the project area. To evaluate the quality of each arrangement, each point arrangement type was handled independently in a distinct project. The findings indicate that the diagonal design is more efficient than the straight configuration, since it produces superior outcomes. The minimum RMSE achieved with the straight configuration is 0.046 m using 3Dsurvey software and 0.049 m using 3DF Zephyr software, whereas the minimum RMSE obtained with the diagonal layout is 0.036 m using 3Dsurvey software and 0.041 m using 3DF Zephyr software. This is due to the fact that the diagonal layout provides greater coverage for the project region, allowing each point cloud to reference more adjacent GCPs. The amount of RMSE drops every time we add a new GCP as a control point for the optimal number of GCPs issue,
but this amount begins to become lower after the 20 control points, but the best results are obtained with the maximum number of GCPs with RMSE equal to 0.036 m. This is because a longitudinal project needs more control points as the surveying area becomes longer, while a broad area project's restricted number of GCPs would suffice. With a difference ranging from 0.755 m with the smallest number of GCPs to 5 mm with the largest number of GCPs, 3Dsurvey software produces somewhat more accurate bundle adjustment findings than 3DF Zephyr software. As a consequence, 3Dsurvey is able to handle bundle modification better than the 3DF Zephyr.

6. Conclusion

The influence of using additional ground control points to reference the three-dimensional model of an unmanned aerial vehicles survey using a low conventional UAV called the DJI Mavic 2 Pro, utilizing 2 distinct program packages for processing the photos and create three-dimensional model, Orthomosic, as well as DTM, after referencing the three-dimensional model by making adjustments to the camera positions and orientations that use the full bundle adjustment technique, were examined in this research. 3Dsurvey Mapper and 3DF Zephyr were the programs utilized. To assess the impact of each arrangement pattern on the accuracy, the GCPs are dispersed differently across the project area. We discovered that a diagonal layout is better than a straight configuration for obtaining a low level of RMSE for the check points. The ideal number of GCPs is proportional to the longitudinal project's size, with RMSE almost equal for GCPs greater than 23. The research concludes that the minimum gap between adjacent GCPs ought to be no over than 100 meters in order to achieve reasonably precise results in low-cost UAV mapping.

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