# GeomatikaDroid: An Android application for improving theodolite measurement

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**Abstract.** In the era of the fourth industrial revolution, the implementation and integration of digital technology and physical processes are unavoidable in which teaching and learning geomatic are included. In the field, students generally make mistakes in calculation of horizontal distance and height difference that are caused by the error in staff reading or/and its recording. The general aim of this research is to develop geomatic application on android, so that it will be portable and easy to use in order to reduce the parallax and staff reading error in theodolite. In the design and development of GeomaticDroid Application, the Java and PHP programming languages were implemented and data were recorded in MySQL. Application testing and debugging were conducted using Android 7.0. In the field testing, GeomatikaDroid has shown consistencies in clarity, better legibility of staff reading and recording compared to conventional staff reading and recording method. GeomatikaDroid has maximum parallax error of 1 mm. Meanwhile, the measurement without GeomatikaDroid makes staff reading error of 18 mm. The z test of two independent samples proved that those two samples have significant differences in error.

## 1. Introduction

Nowadays, in the Industry 4.0 era, the combination of the traditional industries strengths with the latest internet technologies provide a set of technologies that enable smart products integrated into intertwined digital and physical processes [1]. Current surveying and spatial information technology incorporate information, communication technology and user friendly. However, it is not convenient to use in the field because a connection to a computer, such as a laptop, tablet PC, or desktop PC, is needed to obtain the survey results and the coordinates of the surveyed points [2]. Mobile technology has entered into the mainstream society, affecting the lives of many in recent years. This novel technology is slowly making its presence in the educational realm, which accords many opportunities to the learning and training [3]. Android and IOS smartphones, the smart product, are able to provide various applications for daily life use including entertainment and professional applications. Developers have also developed various Android apps for education that provide greater opportunities for the students to learn. It is better than the traditional method of learning as it brings a new kind of experiences for the students [4]. Although Android app in the scope of Geomatics is still limited, researches and developments have been carried out by both of research institutes and universities. For example, the development of GIS application of pipes network for cellular device with Android OS was successfully produced, named MGIS29 and it has a file size 2.93 mb. The development processes were used Java Programming Language [5]. The ALQIDCS is similar GIS application for mobile device, it is a highly flexible and mobile GIS-based system for efficiently collecting and processing near real-time arable land quality index data [6]. Recently, survey has been subjected to automation. The field surveyor with a lot of technical skills and the ability to judge has been replaced by an operator controlled by hardware/software systems. The technical changes have not simply been a refinement of old techniques, but GPS and GIS operate on different principles. The subdivision of geomatics tasks in acquisition, processing, and presentation is no longer valid, as all tasks may be executed in a single integrated system [7]. There are several sources of errors when conducting field measurement using certain instrument, such as instrument, operator and nature. This research focused on human/operator error in the field. In this case, the operators were students that have been trained. Error in distance and differential height calculation might be caused by staff reading error which is the consequence of inadequate field staff reading validation.

Therefore, the aims and objectives of this research are to develop and test an Android-based application to reduce staff reading and parallax error in distances and height differences measurement using low cost survey instruments (analogue theodolite or digital theodolite).

## 2. Materials and methods

The methodology of this research is consisted of problem identification. The common problems that frequently emerge in measurement using low cost device (theodolite). The research was initiated by identifying the common problem of measurement using low cost device (theodolite). After problems were recognized and well identified, the android app was designed. The design was implemented through coding processes in Android Studio as an Integrated Development Environment (IDE) which is equipped with Android SDK and JDK. In client side, Java was used as program language. Meanwhile in server side, PHP was implemented as programming language and MySQL, also utilized as database server.

The app testing and debugging were conducted in Samsung Galaxy J8 Prime with Android 7.0. After the App had shown its consistency and stability, and relatively free of bug, then the app was tested in the field to record topographic mapping including traverse closed of four polygons and 31 detail points. In order to evaluate the reliability of the apps in term of facilitating user to validate staff reading, reduce parallax error, and make clarity record during measurement, the experimental group conducted the measurement using the GeomatikaDroid app, meanwhile the control group did measurement without the app. Several field tests also have been conducted to find another bug, and then the app performance enhancement was conducted base on bug, field test finding and user request. When the app has been proven free of major errors then it was uploaded to play store.

## 3. Results and discussion

Survey data in the form of field book is very important to record the measurement while reading staff is conducted. The survey record in the field book must meet the following criteria: accuracy, integrity, legibility, arrangement and clarity [8]. The first identified problem is that theodolite measurement commonly using conventional manner to record all the field data in paper book and pencil so that the field note tidiness is inconsistence. In the most case, its previous pages are usually better than the continuing page. Sometimes, it is lack of legibility and as well as sometimes it is confusing. Field condition, such as hot weather, raining and human fatigue cause those inconsistencies. The second, problem in survey is possible error which is caused by conventional calculator because there is no reminder whether the data valid or invalid. The third, problem is that there is frequently emerging parallax error dealing with telescope setting. This error will occur if the pointer is not seen from a direction which is exactly perpendicular to the scale. Therefore, the reading will appear to be higher or lower than the actual [9]. So that, the reading staff changes when relative position of eye changes.

In order to avoid the above error, the GeomatikaDroid as android app is developed. The app is designed to help geomatics learning, especially in polygon and topographic measurement. Features in this app include distance and height difference calculator. It is also equipped with reading staff validity check, so that if there is any error in staff reading due to parallax, it can be detected and fixed instantly by telescope resetting and repeating of staff reading when it still in the same point. The other feature of the apps is that it has function to improve legibility and clarity of data recording. The above feature is included in field note menu which is capable to store instrument location, back sight (BS) data and fore sight (FS) data. User can store all survey data and retrieve them in the end of measurement by downloading the csv file. Later, it can be opened and edited in MS excel or the other standard spreadsheet app. User can directly use it or reprocess raw data such as height of instrument, horizontal angle, zenith angle and staff reading.

In distance and height difference calculation, staff reading is needed as upper, middle and lower cross hair. According to Schofield [10], to find horizontal distance (hd), the following formula is used:

$$hd = 100S.cos^2\theta \ \ [10] \tag{1}$$

where S= upper cross hair (ba) – lower cross hair (bb)

$$\theta \ = 90^o - zenith \tag{2}$$

then,

$$hd = 100.(ba - bb).cos^2(90 - zenith) \tag{3}$$

Meanwhile height difference ($\Delta h$) can be calculated as follows:

$$\Delta h = hd.tan\ tan\theta\ + (hi - bt) \tag{4}$$

where hi is the instrument's height and bt is the middle crosshair value in staff reading.

The code that can be used to solve the above formula in java programming language is as follows:

```
double hi, ba, bt, bb, z;
double hd =((0.1)*(ba-bb)*(Math.cos(Math.toRadians(90-z)))*
(Math.cos(Math.toRadians(90-z))));
doubleΔh=(hd*(Math.tan(Math.toRadians(90-z))))+((hi-bt)/1000);
```

The validation in reading staff, which is an effort to reduce the parallax error, is conducted by checking the value of the average of the upper and lower cross hair, then the values are compared to the value of middle crosshair. If the gap between them is less than 1.5 mm then the dialog box in GeomatikaDroid will give the information to the user that the staff reading is valid, and if the value is more than 1.5 mm, the dialog box will inform the user that the value is not valid. And the code for the validity check as follows:

```
double num1 = (ba + bb) / 2;
String number11 = String.valueOf(num1);
double num2 = (num1 - bt);
String number2 = String.valueOf(num2);
TextView tvmsg = new TextView(MainDataProActivity.this);
if ((num2 <=2) && (num2 >= -2)) {
String valid = "reading is valid";
tvmsg.setText("\t Diff(Ba+Bb)/2 and Bt:\n\t" + number2 + "mm \n\t" + valid);
            } else {
String valid = "reading is invalid. Please double check !";
tvmsg.setText("\t Diff(Ba+Bb)/2 and Bt:\n\t" + number2 + "mm \n\t" + valid);  }
```

The result of the reliability test of the app showed that the GeomatikaDroid has consistency in clarity and legibility of its field note feature. What more data distortion in the continuing processes can be minimized as csv file can be directly corrected. In conventional field note, it needs data entry process to the computer that might contribute error in such process if there is not verification and validation of the data. Figure 1 shows the inconsistencies in clarity and legibility of recorded data in the paper between first sheet and third sheet which is measured by Control Group, while Figure 2 and Table 2 show the result of data recording and calculation in GeomatikaDroid and an example of downloaded csv file in spreadsheet respectively.


(a) (b)

**Figure 1**. Conventional field notes of topographic measurement: (a) first sheet and (b) third sheet, both of them showing inconsistencies in legibility, in third sheet is less legible than first sheet.

**Tabel 1**. Result of recording of polygon measurement data and several detailed point.

| Code | Horiz. Angle (β) | Zenith | ba | Bt | bb | Azimuth (α) | hd | dh | X target | Y Target | Z Target | Rem |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1toN | 0 | 0 | NA | NA | NA | 180 | NA | NA | NA | NA | NA | FS |
| P1toP2 | 221.58 | 90.90 | 1148 | 910 | 674 | 221.58 | 47.38 | -0.03 | 968.54 | 964.55 | 99.97 | BS |
| dt 1.1 | 66.66 | 87.07 | 3780 | 3710 | 3640 | 66.66 | 13.96 | -1.36 | 1012.82 | 1005.53 | 98.63 | |
| dt 1.2 | 84.38 | 87.29 | 2380 | 2315 | 2250 | 84.38 | 12.97 | -0.07 | 1012.90 | 1001.26 | 99.92 | |
| dt 1.3 | 139.82 | 87.29 | 2285 | 2225 | 2165 | 139.82 | 11.97 | -0.02 | 1007.72 | 990.85 | 99.97 | |
| dt 1.4 | 195.98 | 89.40 | 1850 | 1790 | 1730 | 195.98 | 11.99 | -0.03 | 996.69 | 988.46 | 99.96 | |
| dt 1.5 | 263.04 | 89.40 | 1850 | 1760 | 1670 | 263.04 | 17.99 | 0.05 | 982.13 | 997.82 | 100.05 | |
| dt 1.6 | 317.70 | 88.88 | 1385 | 1330 | 1275 | 317.70 | 10.99 | 0.51 | 992.60 | 1008.13 | 100.51 | |
| dt 1.7 | 320.59 | 88.88 | 2300 | 2235 | 2170 | 320.59 | 12.99 | -0.35 | 991.75 | 1010.04 | 99.64 | |
| dt 1.8 | 322.50 | 83.69 | 3060 | 2930 | 2800 | 322.50 | 25.68 | 1.54 | 984.36 | 1020.37 | 101.54 | |
| dt 1.9 | 355.53 | 88.52 | 3010 | 2910 | 2810 | 355.53 | 19.98 | -0.76 | 998.44 | 1019.92 | 99.23 | |
| dt 1.10 | 54.36 | 91.40 | 2960 | 2830 | 2700 | 54.36 | 25.98 | -1.83 | 1021.11 | 1015.13 | 98.165 | |

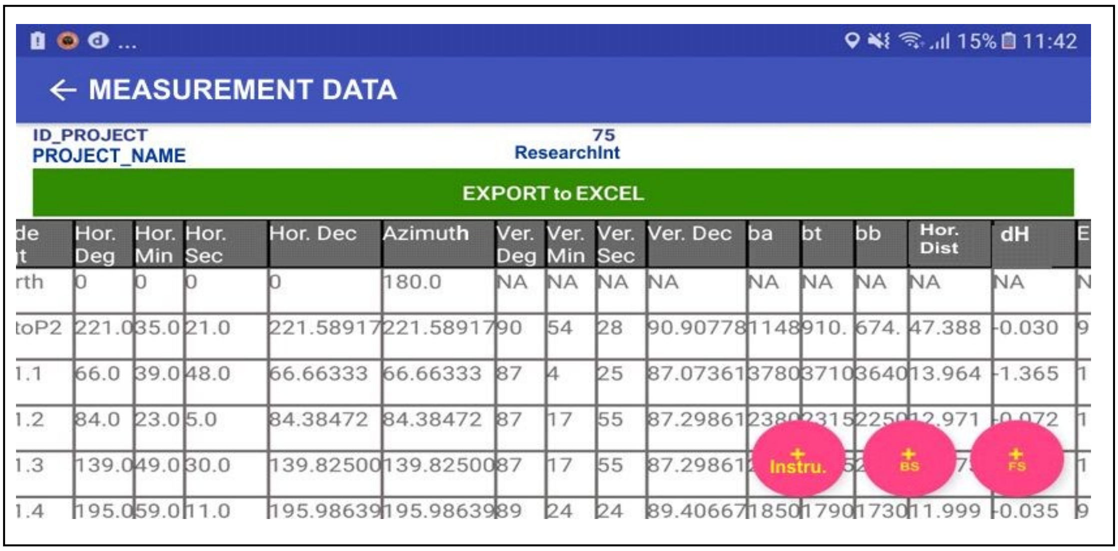


**Figure 2.** An example of field note in GeomatikaDroid app.

The results of staff reading of the two groups are compared to prove the reliability of GeomatikaDroid in minimizing parallax error. Control Group conducted 22 reading and recording; there are 14 differences between bt and ba+bt/2. The biggest difference reaches 18 mm (See Table 2).

**Table 2**. Result of staff reading and validity control of control group.

| No | ba mm | bt mm | bb mm | btt= (ba+bb)/2 | bt – btt |
|---|---|---|---|---|---|
| 1 | 931 | 800 | 669 | 800 | 0 |
| 2 | 2185 | 2100 | 2015 | 2100 | 0 |
| 3 | 2565 | 2500 | 2435 | 2500 | 0 |
| 4 | 1840 | 1800 | 1760 | 1800 | 0 |
| 5 | 2955 | 2800 | 2645 | 2800 | 0 |
| 6 | 775 | 600 | 425 | 600 | 0 |
| 7* | 1900 | 1800 | 1690 | 1795 | 5 |
| 8 | 2400 | 2300 | 2200 | 2300 | 0 |
| 9* | 3066 | 3025 | 2982 | 3024 | 1 |
| 10* | 2069 | 1982 | 1897 | 1983 | -1 |
| 11* | 2555 | 2400 | 2215 | 2385 | 15 |
| 12* | 1848 | 1650 | 1455 | 1652 | -2 |
| 13* | 1460 | 1406 | 1346 | 1403 | 3 |
| 14* | 830 | 800 | 776 | 803 | -3 |
| 15* | 3538 | 3400 | 3295 | 3417 | -17 |
| 16* | 2320 | 2200 | 2060 | 2190 | 10 |
| 17* | 3695 | 3500 | 3340 | 3518 | -18 |
| 18* | 3855 | 3700 | 3550 | 3703 | -2 |
| 19* | 2565 | 2400 | 2245 | 2405 | -5 |
| 20 | 2030 | 1890 | 1750 | 1890 | 0 |
| 21* | 2790 | 2645 | 2510 | 2650 | -5 |
| 22* | 1965 | 1820 | 1670 | 1818 | 3 |

remarks:
btt=theoretical middle cross hair value
*) reading with error

**Table 3.** Kolmogorov-Smirnov one sample test (*Control Group*).

| | | VAR00001 |
|---|---|---|
| N | | 22 |
| Normal Parameters[a,b] | Mean | -.7273 |
| | Std. Deviation | 7.03178 |
| Most Extreme Differences | Absolute | .201 |
| | Positive | .186 |
| | Negative | -.201 |
| Kolmogorov-Smirnov Z | | .942 |
| Asymp. Sig. (2-tailed) | | .337 |

[a] Test distribution is Normal.
[b] Calculated from data.

Kolmogorov-Smirnov test result shows the sample is normally distributed (Table 3). Experimental group conducted staff reading in the field using GeomatikaDroid as medium to record the notes. The notes are consisted of 36 readings, they show differences in bt and ba+bb/2 only for two points. While the maximum difference is 1 mm (refer to Table 4).

Table 5 shows the result of Kolmogorov-Smirnov test of *sample* of *Experimental Group* showing normal distribution. The significant value is 0.657 which is located outside of transition points of -0.0125< and < 0.0125. Therefore, the error reading of between Control Group and Experimental Group has significant difference (See Table 6).

The error of polygon relative position of two measurements can also be compared. Table 8 shows the coordinates of four points in closed polygon measured by control group. The error of position in x = 0.258 m, in y = 0.420 m, and in z = 0. 202 m. Meanwhile, the result of measurement of experimental group shows relative position of four points of closed polygon as listed in Table 9. With x error = 0.020 m, y error = -0.008 m and z error=0.050 m which are smaller than another group's result.

Another advantage of using GeomatikaDoid is that the time needed for studio work is shorter, because the calculation and transformation from angle and distance to coordinate have been solved by GeomaticDroid. At the moment, GematikaDroid has been published in Google play store for student and professional [11].

**Table 4.** Result of staff reading and validity control of Experimental Group.

| No | ba (mm) | bt (mm) | bb (mm) | btt=(ba+bb)/2 | bt - btt |
|---|---|---|---|---|---|
| 1* | 1148 | 910 | 674 | 911 | -1 |
| 2 | 3780 | 3710 | 3640 | 3710 | 0 |
| 3 | 2380 | 2315 | 2250 | 2315 | 0 |
| 4 | 2285 | 2225 | 2165 | 2225 | 0 |
| 5 | 1850 | 1790 | 1730 | 1790 | 0 |
| 6 | 1850 | 1760 | 1670 | 1760 | 0 |
| 7 | 1385 | 1330 | 1275 | 1330 | 0 |
| 8 | 2300 | 2235 | 2170 | 2235 | 0 |
| 9 | 3060 | 2930 | 2800 | 2930 | 0 |
| 10 | 3010 | 2910 | 2810 | 2910 | 0 |
| 11 | 2960 | 2830 | 2700 | 2830 | 0 |
| 12 | 980 | 740 | 500 | 740 | 0 |
| 13 | 700 | 550 | 400 | 550 | 0 |
| 14 | 4220 | 4060 | 3900 | 4060 | 0 |
| 15 | 1595 | 1500 | 1405 | 1500 | 0 |
| 16 | 1390 | 1340 | 1290 | 1340 | 0 |
| 17 | 1775 | 1700 | 1625 | 1700 | 0 |
| 18 | 1540 | 1500 | 1460 | 1500 | 0 |
| 19 | 1110 | 1000 | 890 | 1000 | 0 |
| 20* | 1507 | 1331 | 1153 | 1330 | 1 |
| 21 | 1070 | 980 | 890 | 980 | 0 |
| 22 | 3690 | 3580 | 3470 | 3580 | 0 |
| 23 | 1700 | 1600 | 1500 | 1600 | 0 |
| 24 | 1540 | 1400 | 1260 | 1400 | 0 |
| 25 | 1420 | 1300 | 1180 | 1300 | 0 |
| 26 | 1500 | 1330 | 1160 | 1330 | 0 |
| 27 | 1450 | 1120 | 790 | 1120 | 0 |
| 28 | 1930 | 1860 | 1790 | 1860 | 0 |
| 29 | 885 | 805 | 725 | 805 | 0 |
| 30 | 2360 | 2260 | 2160 | 2260 | 0 |
| 31 | 2160 | 2050 | 1940 | 2050 | 0 |
| 32 | 1430 | 1330 | 1230 | 1330 | 0 |
| 33 | 1535 | 1470 | 1405 | 1470 | 0 |
| 34 | 1535 | 1470 | 1405 | 1470 | 0 |
| 35 | 1535 | 1470 | 1405 | 1470 | 0 |
| 36 | 1340 | 1100 | 860 | 1100 | 0 |

remarks:
btt= teoretic middle crosshairs value
*) reading with error

**Table 5.** Kolmogorov-Smirnov one sample test.

(Experimental Group)

| | | VAR00002 |
|---|---|---|
| N | | 36 |
| Normal Parameters[a,b] | Mean | .0000 |
| | Std. Deviation | .23905 |
| Most Extreme Differences | Absolute | .472 |
| | Positive | .472 |
| | Negative | -.472 |
| Kolmogorov-Smirnov Z | | 2.833 |
| Asymp. Sig. (2-tailed) | | .000 |

a. Test distribution is Normal.
b. Calculated from data.

**Tabel 6.** Statistical comparison of two groups measurement (z-test).

| Paired Sample Test | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Paired Differences | | | | | | | |
| | Mean | Std. Dev. | Std. Err Mn | 95% Conf. Int Dif. Lower | 95% Conf. Int Dif. Upper | t | df | Sig. (2-tailed) |
| Pair 1 VAR0001-VAR0002 | -0.83333 | 7.8159 | 1.84222 | -4.72009 | 3.05342 | -0.452 | 17 | 0.657 |

**Tabel 7.** Coordinates of polygon, calculated by control groups measurement.

| Polygon | Coordinate | | |
|---|---|---|---|
| | X (m) | Y (m) | Z(m) |
| P1 | 1,000.000 | 1,000.000 | 100.000 |
| P2 | 1,016.326 | 981.132 | 100.370 |
| P3 | 962.750 | 937.664 | 101.073 |
| P4 | 955.225 | 1,005.241 | 101.230 |
| P1’ | 999.742 | 999.580 | 100.203 |

**Table 8.** Coordinates of polygon, calculated by experimental groups measurement.

| Polygon | Coordinate | | |
|---|---|---|---|
| | X (m) | Y (m) | Z(m) |
| P1 | 1,000.000 | 1,000.000 | 100.000 |
| P2 | 968.544 | 964.557 | 99.970 |
| P3 | 940.122 | 973.883 | 99.357 |
| P4 | 934.577 | 1,008.844 | 99.895 |
| P1’ | 999.980 | 1,000.008 | 99.95 |

## 4. Conclusions

The result of the test shows that the field note in GeomatikaDroid has higher consistency in clarity and legibility compared to the conventional field note. Measurement result in GeomatikaDroid has smaller parallax error in staff reading than that of the measurement without GeomatikaDroid aid. GeomatikaDroid has maximum parallax error of 1 mm, meanwhile the measurement without GeomatikaDroid giving maximum staff reading error of 18 mm. The Z-Test of two independent sample staff reading with and without GeomatikaDroid shows a significant difference in error between them with significant value of 0.657. The implication of this research is twofold. Surveyors have smaller error in theodolite measurement and improve the quality of field note. It also reduces time in studio work as it liberates surveyor for entry data and calculate coordinate every point.

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