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SMARTPHONE SURVEY (SENSOR & AR TECHNOLOGY)

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ABSTRACT

This study investigates the potential of modern smartphone hardware and software, including sensors and Augmented Reality (AR) technology, to approximate the accuracy of conventional surveying instruments. We conducted a comparative analysis between smartphone-generated measurements and those obtained using Theodolite and Tape. The ARuler application exhibited the capability to measure distances with a maximum difference of only 2 cm compared to Tape measurements, showcasing the smartphone's precision in length measurements. Similarly, the Compass Pro application provided directional measurements with a maximum difference of 40 minutes when compared to Theodolite readings, indicating its suitability for directional measurements. This research underscores smartphones' potential as valuable tools for surveying tasks, highlighting their ability to approach the accuracy of traditional surveying instruments, and paving the way for more accessible and cost-effective surveying solutions.

Keywords: Smartphone, Augmented Reality (AR), Surveying Instruments, Sensors, Comparative Analysis.

I. INTRODUCTION

Modern devices are invariably equipped with a plethora of integrated sensors meticulously designed to measure an array of physical parameters, encompassing motion, orientation, and diverse environmental conditions. The output from these sensors is characterized by its remarkable precision and accuracy. Such sensors serve as indispensable tools for monitoring three-dimensional device movements, positioning, and dynamic environmental changes in the vicinity of the device. The Android platform supports three broad categories of sensors: Motion sensors,

These sensors measure acceleration forces and rotational forces along three axes. This category includes accelerometers, gravity sensors, gyroscopes, and rotational vector sensors [6]. Environmental sensors, these sensors measure various environmental parameters, such as ambient air temperature and pressure, illumination, and humidity. This category includes barometers, photometers, and thermometers. Position sensors,

These sensors measure the physical position of a device. This category includes orientation sensors and magnetometers [5].

Augmented Reality (AR) is the integration of digital information into the user's environment in real time. Augmented reality holds the promise of creating direct, automatic, and actionable links between the physical world and electronic information. It provides a simple and immediate user interface to an electronically enhanced physical world. The immense potential of augmented reality as a paradigm-shifting user interface metaphor becomes apparent when we review the most recent few milestones in human–computer interaction: the emergence of the World Wide Web, the social web, and the mobile device revolution [4]. The trajectory of this series of milestones is clear: First, there was an immense increase in access to online information, leading to a massive audience of information consumers. These consumers were subsequently enabled to also act as information producers and communicate with one another, and finally were given the means to manage their communications from anywhere, in any situation. Yet, the physical world, in which all this information retrieval, authoring, and communication takes place, was not readily linked to the users' electronic activity. That is, the model was stuck in a world of abstract web pages and services without directly involving the physical world. A lot of technological advancement has occurred in the field of location-based computing and services, which is sometimes referred to as situated computing. Even so, the user interfaces to location-based services remain predominantly rooted in desktop-, app-, and web-based usage paradigms [4].

The primary objectives of this project revolve around the utilization of smartphone hardware and software to employ modern surveying techniques, with the aim of achieving several key goals. First, the project seeks to investigate the smartphone's capacity for accurate length measurements. Secondly, it aims to assess the smartphone's precision in directional measurements. Thirdly, the project explores methodologies to derive coordinates utilizing length and azimuth data acquired through smartphone technology. Additionally, the research involves a comparative analysis, contrasting the results obtained from smartphone-based measurements with those obtained using conventional surveying instruments such as theodolites and tape measures. Lastly, the project delves into strategies aimed at enhancing smartphone accuracy, with the ultimate objective of bridging the gap between smartphone-based surveying and traditional surveying instruments.

Two noteworthy studies have explored the accuracy and reliability of smartphone applications for measurements. In a study conducted by Jim Galbraith and Armando Rodriguez, published on TechHive in October 2013, the focus was on applications used for measuring directions. The researchers examined numerous smartphones and provided data showcasing measurements obtained from these devices in comparison to actual measurements taken using a physical compass, Suunto A-10 recreation compass. To rigorously assess the accuracy of smartphone compasses, the tests were conducted a minimum of three times on each phone, with the compass apps being restarted between trials. It was observed that the presence of other phones in proximity had an impact on the compass readings, with deviations reaching a maximum of 12 degrees.

In a separate study by Mike Matthews in September 2018, the emphasis shifted to applications designed for distance measurements. Matthews analyzed several apps and provided data comparing their measurements to actual measurements acquired using a physical metal tape measure. The study revealed that, in this case, the errors reached a maximum of 2.75 meters.

These two studies underscore the importance of assessing the accuracy of smartphone-based measurements, whether for directions or distances, and the variations in accuracy levels among different smartphone applications. Such assessments are crucial for ensuring the reliability of smartphone technology in various practical applications.

These combined literature reviews provide valuable insights into the strengths and limitations of smartphone applications for measurements, shedding light on their potential for both precision and error in real-world scenarios.

II. METHODOLOGY

This chapter encompasses a comprehensive approach to measurements, covering both directions and distances, employing both mobile devices and traditional surveying instruments.

The study begins with a meticulous traverse survey conducted using traditional surveying instruments - Theodolite and Tape. A closed-loop traverse is established with precision, ensuring accurate measurements. This foundational step provides a baseline for subsequent comparisons.

Following the traditional traverse, the study incorporates modern technology in the form of smartphones, specifically utilizing the Compass Pro and ARuler applications. These applications are employed in conjunction with a rope-based methodology to facilitate measurements of both directions and distances. This combination of smartphone technology and practical measurement techniques allows for a comprehensive evaluation of the accuracy and reliability of mobile devices in comparison to traditional surveying instruments.

By conducting measurements using both mobile devices and surveying instruments, this methodology ensures a robust and comparative assessment of the capabilities and accuracy of each approach, providing valuable insights into their respective strengths and limitations.

Azimuths will be measured by using Compass pro Application and Distance will be measured by using ARuler application.

Smartphone Measurements

The smartphones have a small magnetometer built in, which can measure the Earth's magnetic field. This information is combined with an accelerator that acquires information regarding the phone's position in space. It can pinpoint the phone's position and can measure their tilt and movement. The information provided by these devices means that the compass app can display cardinal directions no matter which orientation the phone is in [5] [6].

ACCELEROMETER, Measures the acceleration force in m/s2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity. (Motion detection (shake, tilt, etc.)).

GYROSCOPE, Measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z). (Rotation detection (spin, turn, etc.)).

MAGNETIC_FIELD, Measures the ambient geomagnetic field for all three physical axes (x, y, z) in μT. (Creating a compass) [5] [6], as shown in figure 1:

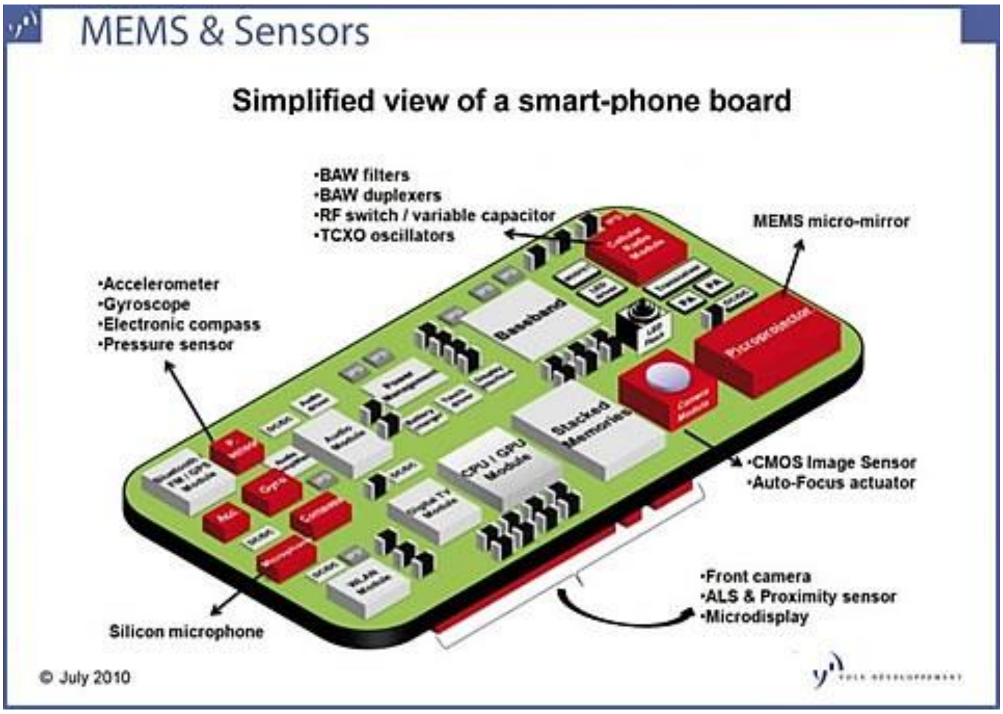

Figure 1: smartphone sensors.

The magnetometer sensor in your tablet or smartphone also utilizes modern solid-state technology to create a miniature Hall-effect sensor that detects the Earth's magnetic field along three perpendicular axes X, Y and Z. The Hall-effect sensor produces voltage which is proportional to the strength and polarity of the magnetic field along the axis each sensor is directed. The sensed voltage is converted to digital signal representing the magnetic field intensity. Other technologies used for magnetometer may include magneto resistive devices which change the measured resistance based on changes in the magnetic field.

The magnetometer is enclosed in a small electronic chip that often incorporates another sensor (typically a built-in accelerometer) that helps to correct the raw magnetic measurements using tilt information from the auxiliary sensor.

Accelerometers are placed in various locations on board, but most important is being away from signal receivers (such as Wi-Fi), to avoid the waves effect.

When working with a map and compass there are usually three different north to be considered: True North, Grid North, and Magnetic North, as shown in figure 2:

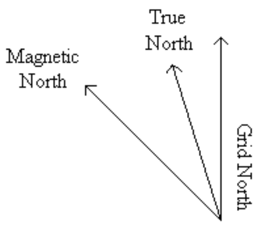

Figure 2: Types of north.

A compass needle points to the magnetic north pole. The magnetic north pole is currently located in the Baffin Island region of Canada, and from the UK, is west of true north. The horizontal angular difference between True North and Magnetic North is called MAGNETIC VARIATION or DECLINATION.

The foundational definition of Augmented Reality (AR), put forth by Azuma in his seminal 1997 survey paper, outlines three essential characteristics that are universally acknowledged in the field. Azuma's definition stipulates that AR must seamlessly integrate virtual elements with the real world, enable real-time interactivity, and ensure precise registration in three-dimensional space. These three core attributes collectively constitute the essence of Augmented Reality as a technology and a concept. A complete AR system requires at least three components: a tracking component, a registration component, and a visualization component [1] [2].

Hardware components for augmented reality are processor, display, sensors and input devices. Camera and MEMS sensors such as accelerometer, GPS, and solid-state compass, making them suitable AR platforms [4].

Camera images, that process is called image registration, and uses different methods of computer vision, mostly related to video tracking [4].

Augmented reality apps are written in special 3D programs that allow the developer to tie animation or digital information in the computer program to an augmented reality "marker" in the real world.

When an AR app receives digital information from a known marker, it begins to execute the marker's code and layer the correct image [4].

The fact is that the sensors in the average smartphone currently have limited power, and the software must work very hard to deduce how those phones are moving and tilting.

That's where errors creep in, and where trust in technology breaks down. But those errors are getting ever smaller over time [4].

Test Accurate of Smartphone:

To assess the accuracy of Augmented Reality (AR) applications, a comprehensive testing methodology will be employed, encompassing various applications and testing scenarios. The evaluation will involve the measurement of distances at different ranges, categorized as short, medium, and large, using both traditional tape measures and smartphone-based measurements. This classification aligns with the actual measurements obtained with tape measures, where short distances are denoted by (5), medium distances by (15), and large distances by (30, 50).

Additionally, to assess the accuracy of compass applications, they will be rigorously tested in conjunction with theodolite instruments, ensuring precise direction measurements. To facilitate the comparison of results from these diverse tests, correlation coefficients will be computed, allowing for a robust assessment of the accuracy and consistency of AR applications and compass tools.

Correlation coefficient in statistics, the Pearson correlation coefficient also referred to as Pearson's, the Pearson product-moment correlation coefficient (PPMCC) or the bivariate correlation is a measure of the linear correlation between two variables X and Y. According to the Cauchy–Schwarz inequality it has a value between +1 and −1, where 1 is total positive linear correlation, 0 is no linear correlation, and −1 is total negative linear correlation. It is widely used in the sciences.

We innovate method, call it (Full Access), it allows smartphone to use all the hardware capabilities to software.

On Samsung device there is application called game launcher that gives games best capabilities (power and resolution…. etc.).

We have developed a method known as 'Full Access,' which empowers smartphones to fully utilize all their hardware capabilities through software enhancements. To illustrate, consider Samsung devices that feature an application called 'Game Launcher.' This application optimizes various aspects such as processing power and screen resolution to provide the best possible experience for gaming and other resource-intensive tasks.

III. MODELING AND ANALYSIS

The selected area under investigation is situated at the Institute of Technology, Civil Department, Baghdad, Iraq, serving as the focal point of this case study, as depicted in Figure 3:

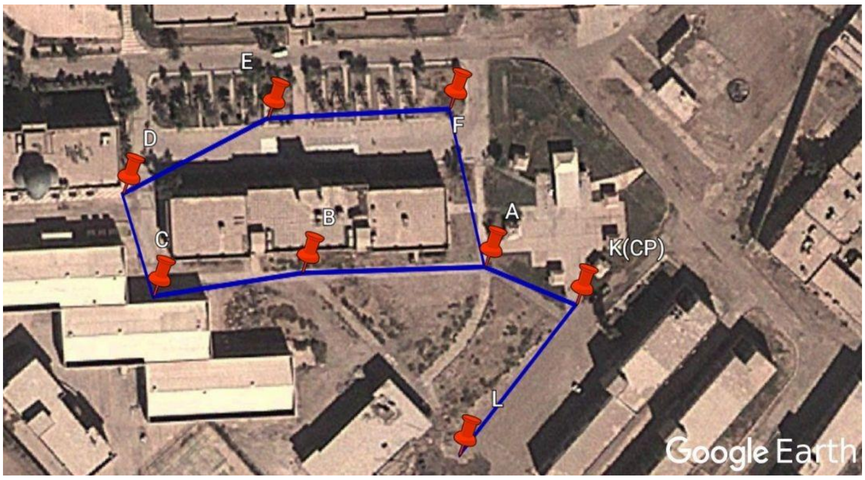

Figure 3: case study.

Smartphone Application:

- Compass pro.
- ARuler.
- Measure.
- AirMeasure.

Computer Program:

- Microsoft excel 2010.
- AutoCAD 2009.
- Google Earth.

Equipment:

- Smartphone (Samsung Galaxy Note 8).
- Theodolite instruments.
- Tripod.
- Tape.
- Rope.

Test Accurate of Smartphone:

By take distances using actual tape and following applications.

Google Measure

Table 1. Compare Actual Tape and Google Measure application.

Height of smartphone approximately 1m				
Actual Tape(m)	5	15	30	50
Measure	5.06	15.1	29.9	51.1
	5.07	15.2	29.9	51.1
	5.04	15.1	29.8	51.1

AirMeasure

Table 2. Compare Actual Tape and AirMeasure application.

Height of smartphone approximately 1m				
Actual Tape(m)	5	15	30	50
AirMeasure	5	15.2	30	50.3
	5	15.2	16.1	50.3
	5	15.1	30	50.4

ARuler

Table 3. Compare Actual Tape and ARuler application.

Height of smartphone approximately 1m				
Actual Tape(m)	5	15	30	50
ARuler(m)	4.99	15	29.93	49.96
	5.02	15.06	28.98	50
	5	14.97	30.02	50
	5	15.06	30.07	49.98

Closer observations to actual tape as shown in table 4:

Table 4. Compare Actual Tape and smartphone applications.

Reality(m)	Augmented reality(m)		
Actual Tape	ARuler	Measure	AirMeasure
5	5	5.04	5
15	15	15.1	15
30	30.02	29.9	30
50	50	51.1	50.3

By solve correlation coefficient equation in Microsoft excel programme using CORREL function: CORREL(Array1;Array2)

Correlation coefficient for application's observation and actual tape as shown in table 5 and figure 4:

Table 5. Compare correlation coefficient for application's observation.

Application	ARuler and actual tape	Measure and actual tape	AirMeasure and actual tape
Correlation coefficient	0.999999873	0.999852445	0.999992023

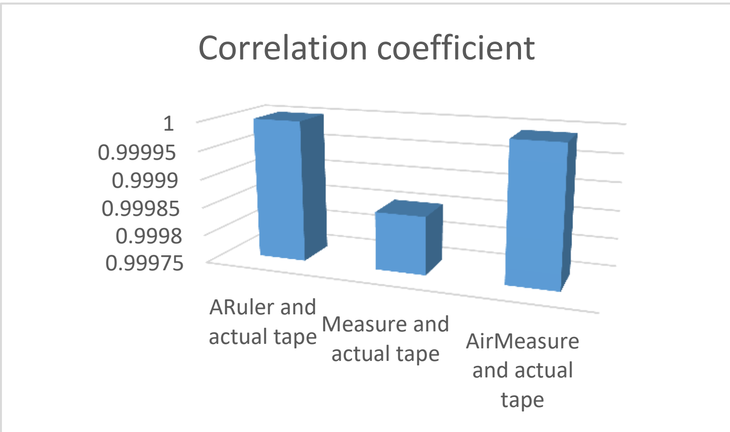

Figure 4: Compare correlation coefficient for application's observation.

Thus, ARuler application is closer to actual Tape.

Compare directions for theodolite and smartphone observation as shown in table 6 and figure 5:

Table 6. Compare directions for theodolite and smartphone.

Side	AZ theodolite(D)	AZ smartphone(D)
AB	268.2138889	268.5333333
BC	261.2563889	261.6833333

CD	343.5475	343.3166667
DE	62.9025	62.33333333
EF	87.3975	86.7
FA	167.4030556	166.6333333

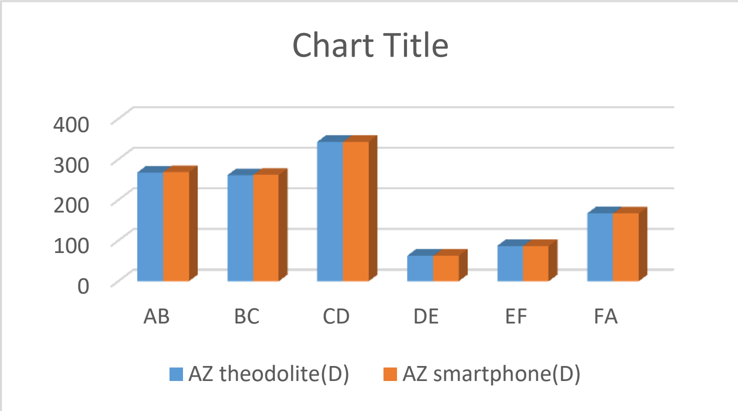

Figure 5: Compare directions for theodolite and smartphone.

Difference in directions as shown in table 7:

Table 7. Difference (theodolite-smartphone) directions.

Side	Difference (theodolite-smartphone)
AB	-0.3194444
BC	-0.4269444
CD	0.2308333
DE	0.56916667
EF	0.6975
FA	0.7697223

By solve correlation coefficient equation in Microsoft excel programme using CORREL function: CORREL(Array1;Array2)

Correlation coefficient = 0.999994003.

Thus, max difference is 0.7deree = 40 minute

IV. RESULTS AND DISCUSSION

This chapter encompasses the experimental work involving traversing and its subsequent adjustment in Microsoft Excel. By taking suitable closed loop traverse with 6 points (each point having 5 measurements) using Theodolite and Tape, As shown in table 8:

Table 8. field observation

Point	Angle (DMS)	Side	Distance(m)
A	79 11 25 - 79 11 03 79 11 26 - 79 11 14 79 11 11	AB	56.61 - 56.60 56.63 - 56.58 56.60
B	186 57 20 - 186 57 27 186 57 23 - 186 57 33 186 57 29	BC	46.47 - 46.45 46.48 - 46.49 46.47
C	97 42 32 - 97 42 27	CD	32.57 - 32.60

	97 42 33 - 97 42 31 97 42 37		32.59 - 32.61 32.60
D	100 38 43 - 100 38 45 100 38 46 - 100 38 42 100 38 39	DE	50.35 - 50.37 50.39 - 50.34 50.38
E	155 30 23 - 155 30 20 155 30 14 - 155 30 17 155 30 21	EF	56.25 - 56.27 56.22 - 56.24 56.26
F	99 59 38 - 99 59 40 99 59 41 - 99 59 39 99 59 40	FA	49.13 - 49.12 49.11 - 49.06 49.05

Then the traverse is adjusted using compass rule on Microsoft Excel2010, As shown in table 9:

Table 9. Compass correction

Correction Dep	Correction Lat	Corrected Dep	Corrected Lat	Easting	Northing
-0.034778179	0.156896289	-56.61127685	-1.60736384	452526.342	3680315.975
-0.028552956	0.128812174	-45.96045996	-6.935655477	452469.7307	3680314.368
-0.020026146	0.09034481	-9.251386189	31.34975664	452423.7703	3680307.432
-0.030945476	0.139605654	44.80634688	23.08195014	452414.5189	3680338.782
-0.034559448	0.155909519	56.15539481	2.71061967	452459.3252	3680361.864
-0.030683737	0.138424858	10.86138131	-48.59930713	452515.4806	3680364.574
		0	0		

The precision of a traverse is expressed as the ratio of linear misclosure divided by the traverse perimeter length:

0.8296541 / 291.224= 1/352.2239

By taking suitable closed loop traverse with 6 points using Smartphone (Compass pro & ARuler Applications) + Rope

Distances measured using ARuler application: Two observations are taken for each point, as shown in table 10:

Table 10. Smartphone field observations for distances

Side	Distance(m)(Normal method)	Distance(m)(Full access method)
AB	56.45,55.98	56.56,56.44
BC	46.13,46.05	46.40,46.36
CD	32.32,31.54	32.66,32.23
DE	50.4,49.96	50.36,50.33
EF	56.21,55.95	56.21,56.29
FA	48.95,49.05	49.84,49.65

NOTE: Underline font is closer observation to Tape.

Azimuths are measured using Compass pro Application.

Adjust the magnetic declination (angle between Magnetic North and the True North direction) for your location from (www.magnetic-declination.com). As shown in figure7:

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Figure 7: Adjust the magnetic declination.

Two observations are taken for each point, as shown in table 11:

Table 11. Smartphone field observations for directions

Side	Azimuth(DM)	B-Azimuth(DM)
AB	269 5 270 32	88 32 89 9
BC	261 41 259 50	80 41 80 12
CD	343 19 345 25	160 25 162 41
DE	62 20 63 35	243 36 245 30
EF	86 42 83 32	268 20 270 40
FA	166 38 169 36	346 30 245 20

Note: Underline font is closer observation to theodolite.

These closer smartphone observation (Distance and Azimuth) to theodolite and Tape, as shown in table 12:

Table 12. Smartphone field observations for directions

Side	Distance(m)	Azimuth(D)
AB	56.56	268.5333333 (from back of BAZ)
BC	46.4	261.6833333
CD	32.66	343.3166667
DE	50.36	62.33333333
EF	56.21	86.7
FA	49.84	166.6333333

Then the traverse is adjusted using compass rule on Microsoft Excel2010 as shown in table 13:

Table 13. Smartphone field observations for directions

CorrectionDep	CorrectionLat	CorrectedDep	CorrectedLat	Easting(m)	Northing(m)
-0.079664797	-0.24313804	-56.62113489	-1.690812022	452526.342	3680315.975
-0.06535443	-0.199462607	-45.97740069	-6.910945917	452469.7209	3680314.284
-0.046001631	-0.140397602	-9.422096089	31.1448138	452423.7435	3680307.373
-0.070932093	-0.216485709	44.53110242	23.16701526	452414.3214	3680338.518
-0.079171821	-0.241633473	56.03762169	2.994040483	452458.8525	3680361.685

-0.070199672	-0.214250352	11.45190756	-48.70411161	452514.8901	3680364.679
		0	0		

The precision of a traverse is expressed as the ratio of linear misclosure divided by the traverse perimeter length:

$$1.321036 / 292.03 = 1/ 221.0614.$$

The precision of theodolite and smartphone traverse as it shown in figure 8:

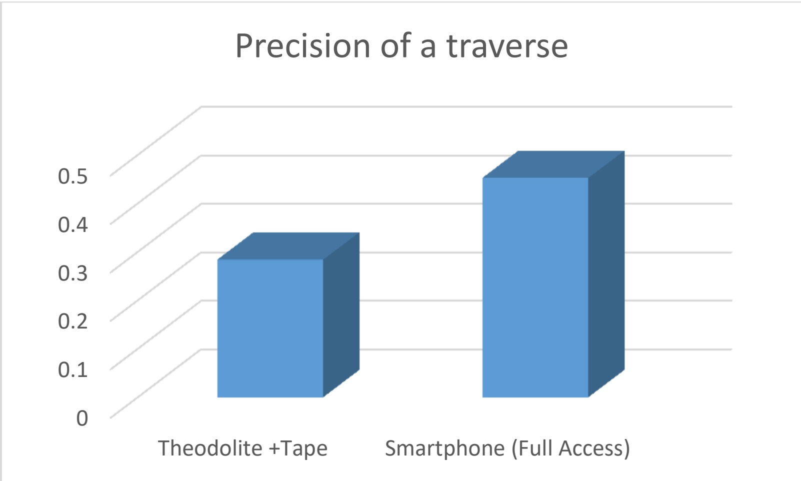

Figure 8: The precision of theodolite and smartphone traverse.

V. CONCLUSION

In this study, we conducted a comprehensive analysis of surveying techniques, particularly focusing on the precision and accuracy of theodolite traverse compared to smartphone-based methods. Our findings reveal the following key insights:

The precision of theodolite traverse is calculated at 1/352.2239, while smartphone traverse, using the Full Access method, exhibits a precision of 1/221.0614.

The ARuler application, employed for distance measurements, exhibits a maximum difference of only 2 cm compared to traditional tape measurements.

The Compass Pro application, used for directional measurements, displays a maximum difference of 40 minutes when compared to theodolite readings.

The test of accuracy for augmented reality, utilizing the ARuler application in the Full Access method, yielded highly favorable results with a correlation coefficient of 0.999999873, signifying a strong positive linear correlation between ARuler measurements and actual tape measurements.

Similarly, the accuracy test for compass measurements in the Full Access method showed promising results with a correlation coefficient of 0.999994003, indicating a robust positive linear correlation between theodolite and smartphone compass directions.

It's worth noting that our findings align with the literature review, where smartphone compass error was reported to reach a maximum of 12 degrees, and smartphone tape measurements exhibited a maximum error of 2.75 meters.

These findings collectively underscore the potential of smartphones, especially when augmented with Full Access capabilities, as valuable tools in the field of surveying, demonstrating competitive accuracy with traditional instruments.

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