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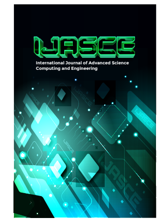

Accuracy Comparison Between Easy Qibla and Total Station

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***Abstract*—Easy Qibla is a mobile app developed by ESERI, UniSZA, that, in addition to the direction of Qibla, provides the azimuth and altitude of the Sun and the Moon at the current time. This data is regularly used by Falak or astronomy researchers; therefore, the accuracy is critical. This study aims to compare the azimuthal accuracy of Easy Qibla and a total station by measuring the actual azimuths of the Sun and the Moon. A total station is installed at station 1, with station 2 designated as the reference object (RO). The azimuth from station 1 to station 2 is determined by a GPS device. Sixty-nine readings were taken by observing both the Sun and the Moon. In each observation, screenshots of Easy Qibla were taken, thus capturing the actual time azimuth. The corresponding azimuth of the Sun or the Moon shown on the total station display was recorded. Both readings are tabulated and then subtracted to obtain the error. Results from 69 readings indicate that the minimum error is 0.0002°, the maximum is 0.26°, and the mean is 0.06°. Data collected on a different day may yield different results due to differences in the Sun's decline. The errors include, but are not limited to, human error and total station error. In conclusion, the results indicate that errors are insignificant in fields with considerably low accuracy, such as determining the qibla or observing the new moon.**

***Keywords*—Easy Qibla; azimuth; error; total station; application.**

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I. INTRODUCTION

Salah is a form of prayer for Muslims and a fundamental, most frequent obligation for every Muslim worldwide. Salah comprises several principles and conditions that the performer must comply with, one of which is facing the qibla [1]. In the Quran, Surah Al-Baqarah, Verse 149, "From whatsoever place thou issue, turn thy face towards the Holy Mosque; it is the truth from thy Lord. God is not heedless of the things you do." [2].

Other than salah, which requires Muslims to face the qibla, numerous other rituals and acts also encourage Muslims to perform them while facing the qibla and therefore elevating the qibla as a fundamental part of Islam [3]. Qibla is defined as the direction toward the Haram Mosque in Mecca [4], situated in present-day Saudi Arabia.

With today's widespread availability of smartphones, anyone can determine the qibla using various applications, including Easy Qibla. Easy Qibla is developed by East Coast Environmental Research Institute (ESERI) of Universiti Sultan Zainal Abidin (UniSZA), Kuala Terengganu. Easy Qibla provides users with local coordinates, the Qibla azimuth, and a satellite image of the locality. The application also provides the azimuth and altitude of the Sun and the Moon in real time, which are frequently used by Falak researchers and enthusiasts to observe the Sun or the Moon and determine the direction of qibla [5], [6]. The azimuth of the sun and the moon is also used to observe Hilal (the new lunar month) [7]. The Islamic lunar month starts with the sighting of the crescent in the western sky, which happens after the conjunction of the sun and the moon [8]. Since the lunar calendar is integral to Islamic practice, observing the Hilal is essential, particularly during the months of Ramadan, Shawal, and Zulhijjah [9], [10]. Ramadhan is the month when Muslims fast from dawn to sunset, and when Ramadan ends, Eid is celebrated in the following month, Shawal. In Zulhijjah, Muslims who meet certain conditions are obligated to perform the hajj in Mecca [11].

Easy Qibla is an application available to all Android smartphone users. Among the general public, Easy Qibla is primarily used to determine the Qibla direction, particularly in unfamiliar places where the Qibla direction is unknown [12]. For researchers and Falak practitioners, Easy Qibla is mostly used to obtain data of the Sun and the Moon, whether to determine the direction of Qibla or to observe the new moon. In determining the direction of qibla, the Sun or the Moon is used as a reference object, whereas a measuring tool such as a total station or theodolite is targeted onto the Sun or the Moon, then the azimuth of the Sun or the Moon is obtained from Easy Qibla, and set into the total station or theodolite. The total station or theodolite is then turned onto the azimuth of the qibla, which may also be obtained from Easy Qibla [13].

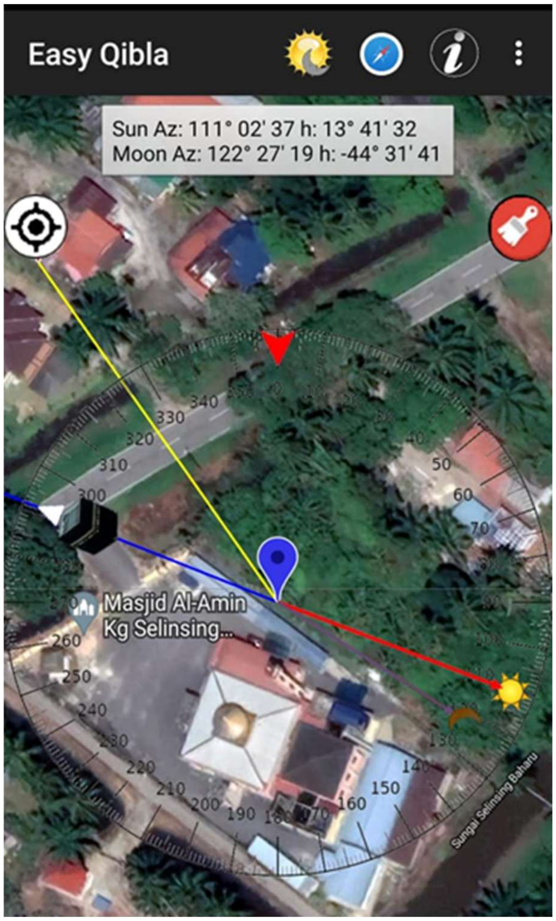


Fig. 1 Screenshot of Easy Qibla

In observing a new moon, Falak practitioners set up a total station or a theodolite and use the Sun as a reference object. Once the Sun is targeted, its azimuth is entered into the equipment. Figure 2 shows the display and key panel of the total station, which are used to view the azimuth and altitude of the target object and to enter the azimuth.

Then, the total station or theodolite was aligned to the Moon's azimuth, and the observation continued until the Moon was sighted [14], [15]. Figure 3 shows an image of the Hilal of Rabiu Lawal (1446 Hijri), observed using a total station and captured with a smartphone on 4 September 2024. Given the widespread use of Easy Qibla in activities that may be considered critical, the credibility of the application's data is essential. Any discrepancies in the data provided by Easy Qibla may affect the research findings and practitioners' conclusions. Therefore, this study aims to compare azimuthal data for the Sun and the Moon, obtained from Easy Qibla, with those obtained using a total station.

Fig. 2 Display and Key Panel of Total Station

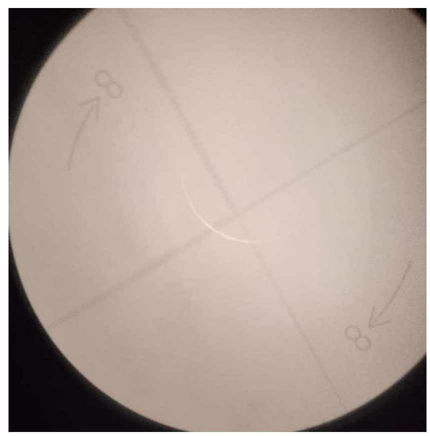


Fig. 3 Hilal observed with Total Station

II. Materials and Methods

A. Materials

Materials or tools involved in this study include TOPCON, a smartphone, and arbitrary ground points. The TOPCON brand total station model GTS-239N comes with a tripod, tribrach, and diagonal eyepieces. The smartphone is equipped with the Easy Qibla application. There are two arbitrary ground points: 1. where the azimuth from one point to the other is known, and 2. where one point is visible from the other.

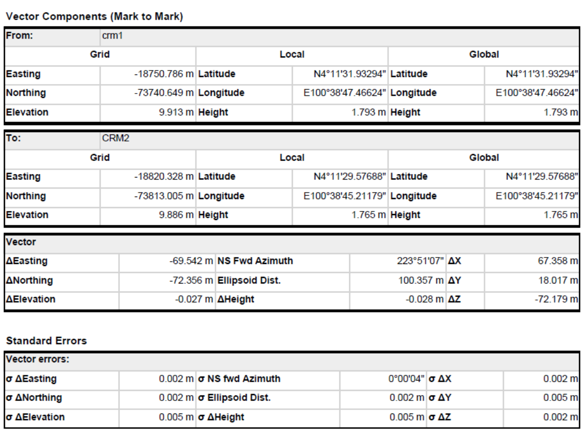
B. Methods

This research employs a quantitative methodology, implemented through observation and data collection. A total station is set up at Station 1, and, using Station 2 as the reference point, the azimuth of Station 2 relative to Station 1 is entered into the total station. The azimuth of Station 2 relative to Station 1 is determined using a GPS system by certified surveyors. Both Stations are located at Taman Seri Wangsa 2, Seri Manjung, Perak. Table 1 presents details of the Stations; Figure 4 shows a screenshot of the Stations form on Google Earth; and Figure 5 shows screenshots of the GPS reports for Station 1 and Station 2.

TABLE I
DETAILS OF STATIONS

Stations	Longitudes	Latitudes
Station 1	100°38'47.46624" E	4°11'31.93294" N
Station 2	100°38'45.21179" E	4°11'29.57688" N
Azimuth of Station 2 from Station 1 is 223°51'07" with a distance of 100.357m		

Fig. 4 Printscreen of Station 1 and Station 2 from Google Earth


Vector Components (Mark to Mark)

From:	crm1				
Grid		Local		Global	
Easting	-18750.786 m	Latitude	N4°11'31.93294"	Latitude	N4°11'31.93294"
Northing	-73740.649 m	Longitude	E100°38'47.46624"	Longitude	E100°38'47.46624"
Elevation	9.913 m	Height	1.793 m	Height	1.793 m

To:	CRM2				
Grid		Local		Global	
Easting	-18820.328 m	Latitude	N4°11'29.57688"	Latitude	N4°11'29.57688"
Northing	-73813.005 m	Longitude	E100°38'45.21179"	Longitude	E100°38'45.21179"
Elevation	9.886 m	Height	1.765 m	Height	1.765 m

Vector					
ΔEasting	-69.542 m	NS Fwd Azimuth	223°51'07"	ΔX	67.358 m
ΔNorthing	-72.356 m	Ellipsoid Dist.	100.357 m	ΔY	18.017 m
ΔElevation	-0.027 m	ΔHeight	-0.028 m	ΔZ	-72.179 m

Standard Errors

Vector errors:					
σ ΔEasting	0.002 m	σ NS fwd Azimuth	0°00'04"	σ ΔX	0.002 m
σ ΔNorthing	0.002 m	σ Ellipsoid Dist.	0.002 m	σ ΔY	0.005 m
σ ΔElevation	0.005 m	σ ΔHeight	0.005 m	σ ΔZ	0.002 m

Fig. 5 Print screen of the GPS report

The azimuth of Station 2 relative to Station 1 was determined using GPS by Sr. Nasarularifin bin Kamarudin on 18 May 2024. The GPS requires that the distance between the two stations be at least 70 meters, and that one station be visible from the other. That is how the locations of both Stations were selected.

For data collection, the total station is set up at Station 1, and a prism reflector is at Station 2. In this study, a TOPCON GTS-239N total station was used. Using the total station, the prism is targeted, and the horizontal value (HSET) is set at 223°51'07", as determined by the GPS. In this case, the prism reflector at Station 2 is the reference object, and the Sun and the Moon are the ones that would be surveyed. Then, the Easy Qibla application is enabled on the smartphone, and it must be refreshed to ensure the location is updated. The total station is aimed at the Sun and the Moon by placing the crosshair at the top or bottom of their respective circumferences. The illustration of how the sun and the moon are targeted is shown below in Figure 6. Note that for the picture on the left, the crosshair is targeted at the bottom of the circumference of the sun. This aiming method provides a clearer optical reference for the observer: the horizontal line is adjusted to touch the bottom of the sun, and the vertical line is adjusted to align with the bottom of the sun's circumference. This way, the data obtained is more accurate since we have reduced one type of error. On the right side is the illustration of aiming at the center of the sun. This method incurred greater error because it is harder for the observer to aim directly at the sun.

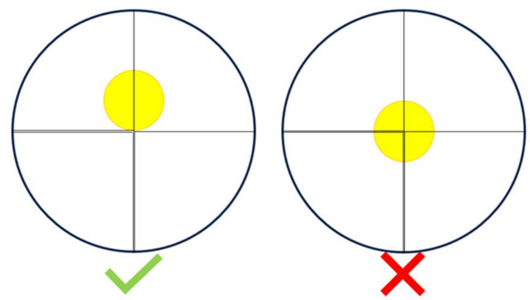


Fig. 6 Illustration of how the sun (or moon) is targeted using a Total Station

Once the target is deemed precise, a screenshot of Easy Qibla is taken, capturing the azimuth of the Sun and the Moon at that time. Meanwhile, the azimuth shown on the total station's display panel is also recorded. This process is repeated multiple times over several hours to improve the accuracy of the collected data. The values from Easy Qibla, their respective values from the total station, and their differences are tabulated.

III. Results and Discussion

Data were collected on three different days: 21 October 2024 for the Moon and 9 November and 19 December 2024 for the Sun. A similar method was implemented on all occasions. The results are presented in Table 2 below.

TABLE II
DATA COLLECTED AND ERRORS

No	date	time	EQ Az	Actual Az	Error	object	decimal error
1	21-10-24	7:45 am	301°12'02"	301°12'00"	0°00'02"	Moon	0.00055555
2	21-10-24	7:47 am	301°02'24"	301°01'20"	0°01'04"		0.00111111
3	21-10-24	7:49 am	300°55'23"	300°54'05"	0°01'18"		0.02166666
4	21-10-24	7:51 am	300°49'43"	300°49'05"	0°00'38"		0.01055555
5	21-10-24	7:53 am	300°41'28"	300°40'20"	0°01'08"		0.01888888
6	21-10-24	7:54 am	300°36'29"	300°35'20"	0°01'09"		0.01916666
7	21-10-24	7:57 am	300°28'11"	300°27'10"	0°01'01"		0.01694444
8	21-10-24	7:59 am	300°19'02"	300°17'35"	0°01'27"		0.02416666
9	21-10-24	8:00 am	300°17'36"	300°16'20"	0°01'16"		0.02111111

No	date	time	EQ Az	Actual Az	Error	object	decimal error
10	21-10-24	8:00 am	300°15'30"	300°14'00"	0°01'30"		0.025
11	21-10-24	8:01 am	300°12'35"	300°11'50"	0°00'45"		0.0125
12	21-10-24	8:02 am	300°09'01"	300°08'10"	0°00'51"		0.01416666
13	21-10-24	8:04 am	300°03'44"	300°02'50"	0°00'54"		0.015
14	21-10-24	8:05 am	299°59'24"	299°59'15"	0°00'09"		0.0025
15	21-10-24	8:06 am	299°56'20"	299°55'35"	0°00'45"		0.0125
16	21-10-24	8:07 am	299°51'52"	299°50'35"	0°01'17"		0.02138888
17	09-11-24	8:08 am	108°45'06"	108°42'40"	0°02'26"	Sun	0.04055555
18	09-11-24	8:20 am	109°13'46"	109°11'25"	0°02'21"		0.03916667
19	09-11-24	8:23 am	109°23'48"	109°21'25"	0°02'23"		0.03972222
20	09-11-24	8:33 am	109°50'40"	109°48'25"	0°02'15"		0.0375
21	09-11-24	8:34 am	109°53'23"	109°51'20"	0°02'03"		0.03416667
22	09-11-24	8:34 am	109°56'17"	109°53'40"	0°02'37"		0.04361111
23	09-11-24	8:36 am	110°00'42"	109°58'30"	0°02'12"		0.03666666
24	09-11-24	8:37 am	110°03'09"	110°00'40"	0°02'29"		0.04138889
25	09-11-24	8:38 am	110°07'24"	110°04'55"	0°02'29"		0.04138889
26	09-11-24	8:54 am	111°01'06"	110°59'20"	0°01'46"		0.02944444
27	09-11-24	8:55 am	111°05'31"	111°03'25"	0°02'06"		0.035
28	09-11-24	8:56 am	111°09'04"	111°07'15"	0°01'49"		0.03027778
29	09-11-24	9:07 am	111°53'25"	111°51'25"	0°02'00"		0.03333333
30	09-11-24	9:09 am	112°02'30"	112°00'15"	0°02'15"		0.0375
31	09-11-24	9:12 am	112°12'51"	112°10'35"	0°02'16"		0.03777778
32	09-11-24	9:35 am	114°07'26"	114°06'00"	0°01'26"		0.02388889
33	09-11-24	9:36 am	114°11'08"	114°08'40"	0°02'28"		0.04111111
34	09-11-24	9:36 am	114°13'02"	114°10'30"	0°02'32"		0.04222222
35	09-11-24	10:07am	117°27'34"	117°25'45"	0°01'49"		0.03027778
36	09-11-24	10:08am	117°34'50"	117°30'40"	0°04'10"		0.06944444
37	09-11-24	10:09am	117°41'19"	117°38'30"	0°02'49"		0.04694444
38	09-11-24	10:32am	120°53'13"	120°47'55"	0°05'18"		0.08833333
39	09-11-24	10:44am	122°58'56"	122°51'05"	0°07'51"		0.13083333
40	09-11-24	10:45am	123°12'26"	123°05'35"	0°06'51"		0.11416667
41	09-11-24	10:46am	123°18'53"	123°11'35"	0°07'18"		0.12166667
42	09-11-24	10:47am	123°29'17"	123°22'15"	0°07'02"		0.11722222
43	09-11-24	10:56am	125°18'04"	125°10'00"	0°08'04"		0.13444444
44	09-11-24	11:24am	132°11'18"	131°58'05"	0°13'13"		0.22027778
45	09-11-24	11:26am	132°44'44"	132°31'25"	0°13'19"		0.22194444
46	09-11-24	11:29am	133°31'03"	133°18'10"	0°12'53"		0.21472222
47	09-11-24	11:29am	133°44'45"	133°30'50"	0°13'55"		0.23194444
48	09-11-24	11:40am	137°18'53"	137°04'10"	0°14'43"		0.24527778
49	09-11-24	11:47am	139°54'35"	139°38'45"	0°15'50"		0.26388889
50	19-12-24	11:47am	143°30'00"	143°27'35"	0°02'25"		0.04027777
51	19-12-24	11:53am	145°28'14"	145°27'00"	0°01'14"		0.02055555
52	19-12-24	12:16 pm	153°28'11"	153°24'55"	0°03'16"		0.05444444
53	19-12-24	12:39 pm	163°19'57"	163°18'35"	0°01'22"		0.02277777
54	19-12-24	12:41 pm	163°52'05"	163°50'10"	0°01'55"		0.03194444
55	19-12-24	12:42 pm	164°23'02"	164°22'20"	0°00'42"		0.01166666
56	19-12-24	12:49 pm	167°35'26"	167°36'15"	- 0°00'49"		-0.01361111
57	19-12-24	12:53 pm	169°39'39"	169°39'40"	- 0°00'01'		-0.00027777
58	19-12-24	12:57 pm	171°48'36"	171°49'45"	-0°01'09"		-0.01916666
59	19-12-24	13:00pm	173°12'39"	173°13'20"	-0°00'41"		-0.01138888
60	19-12-24	13:05pm	175°20'54"	175°23'00"	-0°02'06"		-0.035
61	19-12-24	13:08 pm	176°59'23"	177°01'40"	-0°02'17"		-0.03805555
62	19-12-24	13:12pm	178°51'33"	178°51'00"	0°00'33"		-0.00916666
63	19-12-24	13:14 pm	180°08'44"	180°11'30"	-0°02'46"		-0.04611111
64	19-12-24	13:17pm	181°36'47"	181°39'45"	-0°02'58"		-0.04944444
65	19-12-24	13:21 pm	183°22'57"	183°28'10"	-0°05'13"		-0.08694444
66	19-12-24	13:25 pm	185°23'25"	185°28'05"	-0°04'40"		-0.07777777
67	19-12-24	13:28pm	186°46'31"	186°50'15"	-0°03'44"		-0.06222222
68	19-12-24	13:32pm	188°33'47"	188°38'20"	-0°04'33"		-0.07583333
69	19-12-24	13:35pm	190°04'40"	190°09'50"	-0°05'10"		-0.08611111

The data collected is tabulated, with the content of column 1 (far left) to column 8 (far right) are; number of data taken, date in dd-mm-yy of the data taken, time of the data taken, azimuth in degree-minute-second (dms) of the sun/moon as captured in Easy Qibla, azimuth in dms of the sun/moon as shown at total station display, the error value subtracted between column4 and column 5, the object of observation, either the sun or the moon, and the and the error values in decimal point. The errors are obtained by deducting total station values from Easy Qibla values. Of the 69 data points collected, Easy Qibla values exceed those from the total station for the first 55 readings, indicating that all errors are positive. The following 14 readings show that Easy Qibla values are smaller than those from the Total Station; thus, the errors are negative. The smallest error is -0.00027777°, corresponding to reading 57 in Table 2, taken on 19 December 2024 at 12:53 pm. The largest error is 0.26388889°, taken on 9 November 2024, at 11:47 am. The average error value of all data is 0.06063636°, while the difference between the largest and smallest number is 0.26361113°. The chart comparing error values with data acquisition time is shown in Figure 6.

As expected, the error is smaller in the early morning, before 10:08 am, as shown in Figure 7, which is less than 0.05°. As the day approaches noon and the Sun reaches the meridian, the error values increase drastically, eventually exceeding 0.25°. The result is consistent with the movement of the Sun and the Moon, with the horizontal shift being minuscule in the early morning and late afternoon. As the Sun and the Moon approach the meridian, the horizontal shift becomes significant [16]. Additionally, the errors include human error, which may add some weight to the results.

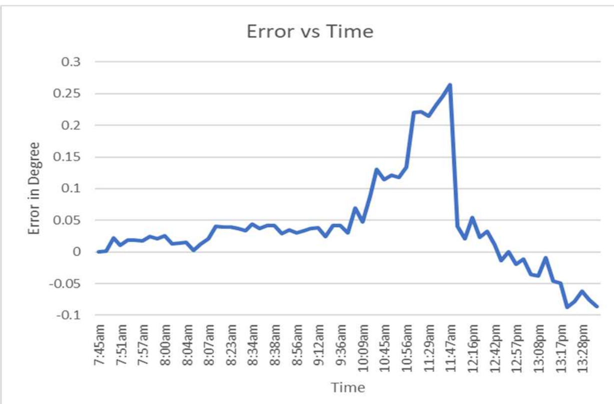


Fig. 7 Error vs Time of Data Taken

IV. Conclusion

In conclusion, the results are consistent with the natural motion of the Sun and the Moon, with increasing error as the day progresses toward noon. This is due to the sun's decline relative to the day of the year. For locations within the tropics, there are only two days in a year when the sun is at the zenith of the location at noon, and the value of declination is zero. But for the rest of the year, the values of decline exist, most of all during summer or winter solstice [17], and therefore, azimuthal value changes drastically for a few hours before and after noon. This phenomenon increases human error in the experiment, thereby cumulatively increasing the total error. The largest error recorded is 0.26388889°, which is still considered small in Falak-related surveys, such as determining the qibla direction and observing the new moon. For the direction of qibla, the tolerance allowed by Fiqh is 3° [18], [19], which is far greater than the maximum error of 0.26388889°. A tolerance of 3° is applied due to the considerable distance between Malaysia and Mecca. Whereas for new moon sighting, the angle of view of the total station and theodolite is usually at 1.5° [20], which is still much greater than the maximum error, and therefore it did not render the Sun and the Moon out of sight of the observer. Even if the moon is sighted with an error at 0.26388889, the crescent of the new moon was still within the range of the total station's scope and therefore allowed the observer to spot the new moon. However, since new moon is sighted during or near sunset time, the error would not have been at the maximum, in fact it was at the minimum, below 0.05° as shown in Fig.4. In conclusion, whether we are using Easy Qibla to either determine angle of qibla or to sight Hilal, or maybe even other purposes, we may certainly claim that Easy Qibla is a reliable application for obtaining azimuthal data of the Sun and the Moon.

Nomenclature

EQ	Easy Qibla
am	ante meridiem
pm	post meridiem
dms	degree minute second
º	degree, unit for measuring angle
'	minute, also known as arcminute, 1/60 of 1º
"	second, also known as arcsecond, 1/60 of 1'

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