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Accuracy of Qibla Direction: Evaluating Smartphone Apps with the Istiwa' Adzam Method

Ketepatan Arah Kiblat: Penilaian Aplikasi Telefon Pintar Menggunakan Kaedah Istiwa' Adzam

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ABSTRACT

Accurate determination of the Qibla direction is crucial for Muslims worldwide, particularly those residing far from Mecca, making it a global concern. In Malaysia, approximately 5000 km away from Mecca, determining the Qibla direction presents significant challenges. A deviation of one degree can result in a discrepancy of up to 180 km from the Ka'ba. Today's technology, especially smartphone apps, provides the simplest and quickest way to find the Qibla. However, their accuracy is often questionable. The purpose of this study is to evaluate the accuracy of Qibla direction in various Qibla direction applications across different smartphone models by comparing it with the istiwa' adzam method. This study employed a field research approach and a descriptive data analysis. Data collection was conducted through observations on July 15 and 16, 2020, at the East Coast Environmental Research Institute (ECERI). The results of this study reveal that the accuracy of the Qibla direction determined using the istiwa' adzam method is consistent. In contrast, several smartphone applications exhibit deviations of up to 15° from the true Qibla direction, whereas the most reliable app, Easy Qiblat (Sun), consistently shows zero deviation across all tested smartphones. This study suggests that it is essential to reevaluate and enhance the Qibla applications currently available on smartphones.

Keywords: Accuracy; istiwa' adzam; islamic astronomy; qibla direction; smartphone applications

ABSTRAK

Penentuan arah kiblat yang tepat adalah penting bagi umat Islam di seluruh dunia, terutamanya mereka yang tinggal jauh dari Mekah, menjadikannya isu antarabangsa yang penting. Di Malaysia, kira-kira 5000 km dari Mekah, penentuan arah kiblat memberikan cabaran yang ketara. Malah sisihan satu darjah boleh membawa kepada percanggahan sehingga 180 km dari Kaabah. Teknologi moden, termasuk aplikasi telefon pintar, menawarkan kaedah yang paling mudah dan cepat untuk menentukan kiblat, tetapi ketepatannya sering dipersoalkan. Tujuan kajian ini adalah untuk menilai ketepatan arah kiblat dalam pelbagai aplikasi arah kiblat di dalam telefon pintar yang berbeza dengan membandingkannya dengan kaedah istiwa' adzam. Kajian ini menggunakan pendekatan kajian lapangan dan analisis data deskriptif. Pengumpulan data dilakukan melalui pemerhatian pada 15 dan 16 Julai 2020 di Institut Penyelidikan Alam Sekitar Pantai Timur (ESERI). Hasil kajian ini mendedahkan ketepatan arah kiblat yang ditentukan menggunakan kaedah istiwa' adzam adalah konsisten, manakala beberapa aplikasi telefon pintar menunjukkan sisihan sehingga 15° daripada arah kiblat sebenar manakala aplikasi paling dipercayai ditemui ialah Easy Qiblat (Sun), di mana ia secara konsisten menunjukkan sisihan sifar merentas semua telefon pintar yang diuji. Kajian ini mencadangkan bahawa penilaian semula dan penambahbaikan aplikasi Kiblat yang digunakan dalam telefon pintar adalah perlu.

Kata kunci: Astronomi Islam; arah kiblat; aplikasi telefon pintar; istiwa' adzam; ketepatan

INTRODUCTION

Muslims are required to perform prayers five times daily when they are certain that the prayer time has begun. (Rojak et al. 2021; Ibrahim et al. 2020). Therefore, accurately determining the Qibla direction is crucial for them. This is because one of the obligatory conditions of prayer is to face the Qibla (Rahmi & Agustio 2021). The command to face the Qibla can be found in the Quranic verses as follows. First is in the Quran Surah al-Baqarah verse 149 which stated that:

وَمِنْ حَيْثُ خَرَجْتَ فَوَلِّ وَجْهَكَ شَطْرَ ٱلْمَسْجِدِ ٱلْحَرَامِ ۖ وَإِنَّهُۥ لَلْحَقُّ مِن رَّبِّكَ ۗ وَمَا ٱللَّهُ بِغَٰفِلٍ عَمَّا تَعْمَلُونَ.

Meaning: And from wheresoever you start forth (for prayers), turn your face in the direction of Al-Masjid-al-Haram (at Makkah), that is indeed the truth from your Lord. And Allah is not unaware of what you do.

And second in the Quran Surah al-Baqarah verse 150:

وَمِنْ حَيْثُ خَرَجْتَ فَوَلِّ وَجْهَكَ شَطْرَ ٱلْمَسْجِدِ ٱلْحَرَامِ ۚ وَحَيْثُ مَا كُنتُمْ فَوَلُّوا۟ وُجُوهَكُمْ شَطْرَهُۥ لِئَلَّا يَكُونَ لِلنَّاسِ عَلَيْكُمْ حُجَّةٌ إِلَّا ٱلَّذِينَ ظَلَمُوا۟ مِنْهُمْ فَلَا تَخْشَوْهُمْ وَٱخْشَوْنِى وَلِأُتِمَّ نِعْمَتِى عَلَيْكُمْ وَلَعَلَّكُمْ تَهْتَدُونَ

Meaning: And from wheresoever you start forth (for prayers), turn your face in the direction of Al-Masjid-al-Haram (at Makkah), and wheresoever you are, turn your faces towards, it (when you pray) so that men may have no argument against you except those of them that are wrong-doers, so fear them not, but fear Me! - And so that I may complete My Blessings on you and that you may be guided.

This obligatory is also derived from a hadith reported by Abu Huraira (Sahih Muslim, no. Hadith 886), where the Prophet Muhammad PBUH, while in a corner of the mosque, instructed a man who had completed his ablution and wished to pray to face the Qibla (Akbar & Mustaqim 2022). As narrated by Al-Hajjaj (2007) in hi compilation *Sahih Muslim* (Hadith No. 886), the Prophet Muhammad PBUH stated:

حَدَّثَنَا أَبُو بَكْرِ بْنُ أَبِي شَيْبَةَ، حَدَّثَنَا أَبُو أُسَامَةَ، وَعَبْدُ اللَّهِ بْنُ نُمَيْرٍ، ح وَحَدَّثَنَا ابْنُ نُمَيْرٍ، حَدَّثَنَا أَبِي قَالاَ، حَدَّثَنَا عُبَيْدُ اللَّهِ، عَنْ سَعِيدِ بْنِ أَبِي سَعِيدٍ، عَنْ أَبِي هُرَيْرَةَ، أَنَّ رَجُلاً، دَخَلَ الْمَسْجِدَ فَصَلَّى وَرَسُولُ اللَّهِ صلى الله عليه وسلم فِي نَاحِيَةٍ وَسَاقَا الْحَدِيثَ بِمِثْلِ هَذِهِ الْقِصَّةِ وَزَادَا فِيهِ " إِذَا قُمْتَ إِلَى الصَّلاَةِ فَأَسْبِغِ الْوُضُوءَ ثُمَّ اسْتَقْبِلِ الْقِبْلَةَ فَكَبِّرْ " .

Meaning: A person entered the mosque and said prayer while the Messenger of Allah (ﷺ) was sitting in a nook (of the mosque), and the rest of the hadith is the same as mentioned above, but with this addition:" When you get up to pray, perform the ablution completely, and then turn towards the Qibla and recite takbir. "

Based on the Quranic verses and hadith mentioned above, it is clear that Muslims are obligated to orient themselves towards the Qibla during prayer. In addition, facing the Qibla is also a mandatory practice for Muslims during circumambulation (*tawaf*) and the burial of the deceased. Meanwhile, it is recommended during supplication, recitation of the Quran, and the slaughtering of animals for regular consumption, sacrificial offerings (*korban*), as well as *aqiqah* ceremonies (Jamil, Sakirman & Ardliansyah 2022).

This requirement poses no issue for Muslim communities residing in areas near Mecca as the position of the Ka'ba can be easily determined. Conversely, for countries located far from Mecca, determining the Qibla direction is not an easy matter, especially for those situated thousands of kilometers away from Mecca (Mackenzie 2001). In Malaysia, approximately 5000 km away from Mecca, determining the Qibla direction presents significant challenges. Even a one-degree deviation can lead to a discrepancy of up to 180 km from the Ka'ba (Zaki et al. 2019). Regarding this issue, scholars from the four major Islamic schools—Ḥanafi, Maliki, Shafi'i, and Ḥanbali—hold differing views on the direction of the Qibla for Muslims outside the city of Mecca (Ikhsan, Zaki & Ali 2019).

LITERATURE REVIEW AND RESEARCH BACKGROUND

According to Mujab (2016), in his study on the Qibla from the perspective of the four major Islamic jurisprudence schools, the Hanafi, Maliki, and Hanbali madhabs, hold that those who can see the Ka'ba must face its physical structure (*ain al-ka'ba*) during prayer, while those who cannot see it should face its direction (*jihat al-ka'ba*). This is based on the principle of doing what is within one's capability (*al-maqdur alaih*). In the Shafi'i madhab, there are two major views. First, Imam Muzanni agrees with the other madhabs, while second, Imam Nawawi states that it is obligatory to face the physical Ka'ba, even for those far away, who must have a strong presumption (*dhan*) that they are facing the actual Ka'ba. These differing opinions arise from varied interpretations of hadith and Quranic verses. This is due to the fact that, within the context of Islamic knowledge, the Arabic language plays a crucial role in shaping these interpretations (Mustapa 2023).

Scientific and technological progress has resulted in the development of diverse techniques for ascertaining the Qibla orientation, even over long distances. Integrating these technological advancements with an understanding of Quranic verses is crucial. This integration enhances the interpretation of Quranic texts relevant to specific fields and promotes a more thorough exploration of the Quranic scripture (Hilmi et al. 2024).

Muslims have applied the concept of ijtihad (independent reasoning), based on the legal methodology of *istinbath* that align with *maslahah* and the values of *maqasid al-Shari'ah* to solve a problem that remains relevant across all times and locations (Rijal & Jailani 2024; Qudsy, Ghozali & Faiz 2023) by utilizing contemporary tools and astronomical computations. Extensive research on Qibla determination has been ongoing for centuries. Various methods have been employed to determine the Qibla direction. Non-technological approaches include using natural signs such as constellations, stars, moon phases, wind direction, and the sun (King 1985; King 2005; Rius 2009). Some also use seasons as a reference for Qibla determination. By the 9th century, mathematical methods, particularly spherical trigonometry, were being utilized (King 2019).

In contemporary times, more advanced technologies like theodolites, Ushikata compasses, and Global Positioning System (GPS) have been adopted. However, this method can only be utilized by experts and demands a high level of expertise. For the general public, Qibla direction applications on smartphones are favored for their practicality and ease of use. Moreover, the ownership of smartphones has surged significantly in recent years (Hood 2024). These endeavors aim to assist Muslims in their religious practices, particularly during prayer.

In the present era, spurred by the advancements of the Industrial Revolution 4.0, a plethora of smartphone applications have been developed, particularly Qibla direction apps (Zaki, Wahab & Niri 2020). These apps offer the easiest and fastest method for Muslims to determine the Qibla. However, their accuracy is often questioned. According to Faid et al (2022), using a magnetic compass on a smartphone is prone to errors. This is supported by Ariffin and Arsad (2022), who stated that GPS-based technologies and electronic compasses cannot be used to determine accurate directions in different geographic locations. According to them, this is due to unexpected magnetic north drifting that made the World Magnetic Model (WMM) data accuracy unreliable. Plus, the accuracy of electronic compasses can decrease subject to metallic objects and interference from electromagnetic fields. Moreover, they also stated that Global Positioning System (GPS) signals may encounter obstructions inside buildings in geographically remote areas, extreme weather conditions, and challenging landscapes. As a result, approximately 19.5 million Muslims in Malaysia encounter a concerning issue, as the Qibla direction they have determined using electronic compasses is likely to be incorrect.

Previous research about the Qibla direction applications accuracy on smartphones had been conducted with varying methods and areas of discussion. Research by Rahmi and Agustio (2021) entitled *"Pengukuran Arah Kiblat Tempat Ibadah Dengan Aplikasi Arah Kiblat Dan Azimut Matahari"* was carried out to investigate the comparison between the Qibla direction determined using a Qibla application with the sun azimuth method. The application had been used in this research was android-based Muslim Pro application. This research found that there are discrepancies between the Qibla direction determined using the sun azimuth method and those obtained from the Muslim Pro Qibla application.

Another relevant study on the accuracy of Qibla direction applications on mobile was performed by Sriani and Ukhti (2022) using the Quran Kemenag Version 2.1.4 application. Zaki et al. (2019) employed the Easy Qibla 3-in-1 application with an Oppo A33F model. Meanwhile, Zaki and Anuar (2018) tested 20 different applications using the Asus Zenfone 2 and compared it with the Huawei P9 Lite. All these studies indicate that deviations occur when using Qibla applications compared to the true Qibla direction.

Based on previous studies, researchers have primarily focused on specific smartphone models and particular Qibla direction applications. However, people use a wide range of smartphone models beyond those studied. With the rapid evolution of smartphone technology, there are countless models with varying hardware and software capabilities. Consequently, the findings from existing research may not be applicable to many devices that users currently own. Furthermore, applications vary widely in terms of their algorithms, reliance on device sensors, and accuracy. Thus, there is a need for a comprehensive comparative analysis that evaluates multiple smartphone models and a broader array of applications simultaneously. Such a study would provide a more holistic view of how different combinations of devices and applications perform in determining the Qibla direction.

This highlights a gap in the literature, as there is a lack of research specifically investigating the accuracy of various Qibla direction applications across different smartphone models. Given the importance of accurate Qibla direction for Muslims, this study aims to rigorously assess the accuracy of various Qibla direction applications across different smartphone models and provide valuable input and guidance to the public in choosing a phone, as well as recommendations for phone companies and Qibla direction applications developers to enhance the accuracy of their devices and apps.

METHODS

This study employed a field research approach combined with descriptive data analysis, methodically divided into three phases: Preliminary, Data Collection, and Data Processing and Analysis. Figure 1 illustrates the detailed methodology employed in this study.

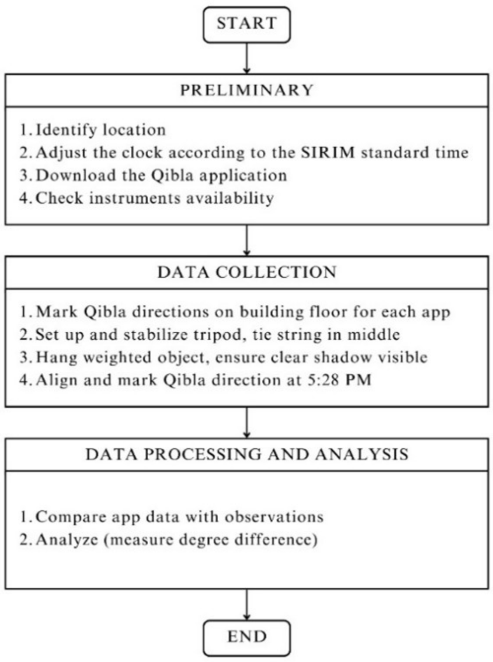

FIGURE 1. Methodology of research

In the Preliminary Phase, the first step was to select an appropriate location—an open area with direct sunlight exposure to prevent shadow interference. The chosen coordinates for this survey were latitude 5.3881084° North and longitude 103.0952912° East at East Coast Environmental Research Institute (ESERI), which fulfil the criteria of open area with direct sunlight exposure. Moreover, this institute serves as the central hub for Falak study and development in East Coast of Malaysia, making it more significant to have the most accurate Qibla direction. Meanwhile the Ka'ba coordinate latitude 21.4224779° North and longitude 39.8251832° East at Saudi Arabia. Following this, it was imperative to align timekeeping instruments accurately by verifying them through Standard and Industrial Research Institute of Malaysia (SIRIM) by calling 1051 or visit the website at https://mst.sirim.my/ or cross-checking with the time displayed on television or radio broadcasts. This step was crucial to ensure the timing precision of all observations, particularly when employing the *istiwa' adzam* method. The *istiwa' adzam* method was selected for this research due to its high accuracy, as the sun's shadows worldwide will point directly towards the Ka'ba (Niri, Zaki & Nor 2023).

A variety of smartphones from different manufacturers and models were then gathered to evaluate the consistency and accuracy of various Qibla direction applications across different devices. Five Android models as seen in Table 1 (Vivo Y31L, Asus Zenfone 2, Xiomi Redmi 4A, OnePlus 6, Realme 3 Pro) and one Apple model (iPhone 7 Plus) were tested using multiple Qibla direction applications, including Easy Qiblat (both compass and sun shadow methods), Waktu Solat by Teno Media, Waktu Solat Malaysia by Murad Mohd Zain, Muslim Pro, Al-Qur'an Melayu, and My Solat by JAKIM.

TABLE 1. Specifications of smartphone models used in the study

Model	Specification		
Vivo Y31L	Platform	OS	Android 5.1 (Lollipop), Funtouch 2.1
		Chipset	Mediatek MT6580 (28 nm)
		CPU	Quad-core 1.3 GHz Cortex-A7
		GPU	Mali-400MP2
	Comms	WLAN	Wi-Fi 802.11 b/g/n, hotspot
		Bluetooth	4.0, A2DP
		Positioning	GPS
	Features	Sensors	Accelerometer, proximity, compass
Asus Zenfone 2 ZE551ML	Platform	OS	Android 5.0 (Lollipop), upgradable to 6.0 (Marshmallow)
		Chipset	Intel Atom Z3580 (4 GB RAM model)
		CPU	Quad-core 2.3 GHz (4 GB RAM model)
		GPU	PowerVR G6430
	Comms	WLAN	Wi-Fi 802.11 a/b/g/n/ac, Wi-Fi Direct, hotspot
		Bluetooth	4.0, A2DP, EDR
		Positioning	GPS, GLONASS
	Features	Sensors	Accelerometer, gyro, proximity, compass
Xiomi Redmi 4A	Platform	OS	Android 6.0.1 (Marshmallow), MIUI 10
		Chipset	Qualcomm MSM8917 Snapdragon 425 (28 nm)
		CPU	Quad-core 1.4 GHz Cortex-A53
		GPU	Adreno 308
	Comms	WLAN	Wi-Fi 802.11 b/g/n, Wi-Fi Direct
		Bluetooth	4.1, A2DP, LE
		Positioning	GPS, GLONASS, BDS
	Features	Sensors	Accelerometer, gyro, proximity
OnePlus 6	Platform	OS	Android 8.1 (Oreo), upgradable to Android 11, OxygenOS 11.1.1.1
		Chipset	Qualcomm SDM845 Snapdragon 845 (10 nm)
		CPU	Octa-core (4x2.8 GHz Kryo 385 Gold & 4x1.7 GHz Kryo 385 Silver)
		GPU	Adreno 630
	Comms	WLAN	Wi-Fi 802.11 a/b/g/n/ac, dual-band, Wi-Fi Direct, DLNA
		Bluetooth	5.0, A2DP, LE, aptX HD
		Positioning	GPS, GLONASS, BDS, GALILEO
	Features	Sensors	Fingerprint (rear-mounted), accelerometer, gyro, proximity, compass

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Realme 3 Pro	Platform	OS	Android 9.0 (Pie), planned upgrade to Android 10, ColorOS 6
		Chipset	Qualcomm SDM710 Snapdragon 710 (10 nm)
		CPU	Octa-core (2x2.2 GHz Kryo 360 Gold & 6x1.7 GHz Kryo 360 Silver)
		GPU	Adreno 616
	Comms	WLAN	Wi-Fi 802.11 a/b/g/n/ac, dual-band, Wi-Fi Direct
		Bluetooth	5.0, A2DP, LE
		Positioning	GPS, GLONASS
	Features	Sensors	Fingerprint (rear-mounted), accelerometer, gyro, proximity, compass
iPhone 7 Plus	Platform	OS	iOS 10.0.1, upgradable to iOS 15.8.1
		Chipset	Apple A10 Fusion (16 nm)
		CPU	Quad-core 2.34 GHz (2x Hurricane + 2x Zephyr)
		GPU	PowerVR Series7XT Plus (six-core graphics)
	Comms	WLAN	Wi-Fi 802.11 a/b/g/n/ac, dual-band, hotspot
		Bluetooth	4.2, A2DP, LE
		Positioning	GPS, GLONASS, GALILEO, QZSS
	Features	Sensors	Fingerprint (front-mounted), accelerometer, gyro, proximity, compass, barometer

The same Qibla direction applications were downloaded and installed on all selected smartphones to ensure consistency across tests. Additionally, all necessary observational instruments, such as tripods for stability, weights and strings for accurate vertical lines, markers for noting directions, and adhesive tape, were prepared to ensure readiness for data collection.

During the Data Collection Phase, the process commenced with marking the Qibla direction as indicated by each application on the floor and clearly labeling each marking to identify the corresponding application and device. Figure 2 shows the process of marking the Qibla direction in detail. A tripod was set up at the chosen location with a string attached at its center as can be seen in Figure 3, ensuring the tripod was level and stable.

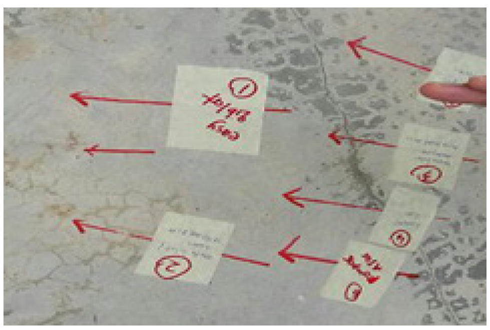

FIGURE 2. Marking and labeling Qibla directions for each application

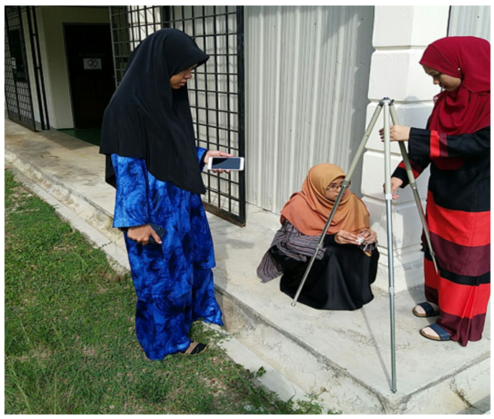

FIGURE 3. Setting up the tripod and attaching the string

A weight was tied to the end of the string as demonstrated in Figure 4, allowing it to hang straight down and act as a plumb line, casting a clear and accurate shadow. It was ensured that the shadow cast by the weighted string was distinct and visible to the naked eye, with adjustments made as necessary. The tripod was positioned to avoid any obstruction from sunlight throughout the observation period, maintaining the visibility and accuracy of the shadow. The shadow was carefully observed, and the precise time (5:28 PM) was awaited to record the shadow's position, which is critical for the *istiwa' adzam* method. Finally, the shadow line was extended to the object as in Figure 5, and the Qibla direction was marked on the ground, serving as a reference for comparing the accuracy of different applications.

FIGURE 4. Placing a weighted object at the end of the string

FIGURE 5. The image displayed the shadow line extending toward the object

In the Data Processing and Analysis Phase, cardinal directions were drawn based on true north using a compass to establish a reference framework for analysis. The angular of each application-marked Qibla direction from the true north reference was taken using a projector or protractor, providing a numerical value for the accuracy of each application and *istiwa' adzam*. All measurements were recorded in a prepared table as shown in Table 2, which included columns for smartphone model, application used, the angular direction of the Qibla based on *istiwa' adzam*, the angular direction indicated by the applications, and the angular deviation between these two measurements. The recorded data were then analyzed to identify patterns and evaluate the accuracy of each Qibla direction application. Conclusions were drawn based on the measured deviations, offering recommendations for improving the accuracy of these applications and smartphones.

RESULT AND DISCUSSION

ANALYSIS OF QIBLA DIRECTION ACCURACY IN SMARTPHONE APPLICATIONS ACROSS DIVERSE SMARTPHONE MODELS

This analysis aims to evaluate the accuracy of Qibla direction in various Qibla direction applications across different smartphone models by comparing it with the istiwa' adzam method, which is essential for practicing Muslims during prayer. The data encompasses a variety of smartphone brands and models, with a focus on popular Qibla direction applications. The Qibla direction for each smartphone was measured using multiple applications. Then, these measurements were compared to a reference direction, labeled as *istiwa' adzam*. The differences between this reference and the angles indicated by each application were calculated to determine the deviation. Table 2 presents the angular deviations of the Qibla direction as indicated by various applications on different smartphone models.

TABLE 2. Angular Deviations of Qibla Direction Indicated by Various Applications Across Different Smartphone Models

Type of smartphones Easy Qiblat (Compass)		Type of applications: Easy Qiblat (Sun)	Waktu Solat (Teno Media)	Compass Android	Waktu Solat Malaysia (Murad Mohd Zain)	Muslim Pro	Al-Quran Melayu	My-Solat (JAKIM)	
VIVO Y31L	Istiwa' Adzam	291°	291°	291°	291°	291°	291°	291°	-
	Apps	291°	291°	297°	283°	298°	291°	291°	-
	Deviation	0°	0°	More than 6°	Less than 8°	More than 7°	0°	0°	-
ASUS ZENFONE 2 ZE551ML	Istiwa' Adzam	291°	291°	291°	291°	291°	291°	291°	-
	Apps	283°	291°	293°	287°	294°	284°	289°	-
	Deviation	Less than 8°	0°	More than 2°	Less than 4°	More than 3°	Less than 5°	Less than 2°	-

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XIAOMI REDMI 4A	Istiwa' Adzam	291°	291°	291°	291°	291°	291°	291°	-
	Apps	276°	291°	290°	292°	297°	284°	287°	-
	Deviation	Less than 15°	0°	Less than 1°	More than 1°	More than 6°	Less than 7°	Less than 4°	-
ONEPLUS 6	Istiwa' Adzam	291°	291°	291°	291°	291°	291°	291°	291°
	Apps	289°	291°	-	-	287°	287°	286°	285°
	Deviation	Less than 2°	0°	-	-	Less than 4°	Less than 4°	Less than 5°	Less than 6°
REALME3 PRO	Istiwa' Adzam	291°	291°	291°	291°	291°	291°	291°	291°
	Apps	289°	291°	-	-	286°	289°	285°	291°
	Deviation	Less than 2°	0°	-	-	Less than 5°	Less than 2°	Less than 6°	0°
IPHONE 7 PLUS	Istiwa' Adzam	291°	291°	291°	291°	291°	291°	291°	291°
	Apps	-	-	-	-	-	289°	-	-
	Deviation	-	-	-	-	-	Less than 2°	-	-

For the VIVO Y31L, all applications except Waktu Solat (Teno Media), Compass Android, and Waktu Solat Malaysia (Murad Mohd Zain) showed no deviation (0°) from the reference direction of 291°. The mentioned exceptions showed deviations of greater than 6°, less than 8°, and greater than 7°, respectively. Data from the My-Solat (JAKIM) app was unavailable because the operating system (OS) did not meet the minimum specifications required. This phone is identified as the most reliable for determining the Qibla, as four tested applications demonstrated zero deviation.

For the ASUS Zenfone 2, the Easy Qiblat (Sun) application was the only one that showed no deviations (0°) from the reference direction of 291°. The deviations observed with the other applications were as follows: Easy Qiblat (Compass) showed deviations of less than 8°, Waktu Solat (Teno Media) showed greater than 2°, Compass Android showed less than 4°, Waktu Solat Malaysia (Murad Mohd Zain) showed greater than 3°, Muslim Pro showed less than 5°, and Al-Quran Melayu showed less than 2°. No data was available from the My-Solat (JAKIM) app due to OS requirements.

The Xiaomi Redmi 4A exhibited no deviations (0°) from the reference direction of 291° when utilizing the Easy Qiblat (Sun) application. Minor deviations were observed with the Waktu Solat (Teno Media) and Compass Android applications, at less than 1° and greater than 1°, respectively. Slightly larger deviations were noted for the Waktu Solat Malaysia (Murad Mohd Zain), Muslim Pro, and Al-Quran Melayu applications, measuring greater than 6°, less than 7°, and less than 4°, respectively. However, Easy Qiblat (Compass) showed the largest deviation (<15°), and no data was available from the My-Solat (JAKIM) app due similar reasons as mentioned previously

For the OnePlus 6, both Waktu Solat Malaysia (Murad Mohd Zain) and Muslim Pro apps displayed deviations of less than 4°. Other applications such as Easy Qiblat (Compass), Al-Quran Melayu, and My-Solat (JAKIM) showed deviations of less than 2°, less than 5°, and less than 6°, respectively. Meanwhile, Easy Qiblat (Sun) consistently indicated the correct direction (291°) with no deviations observed. However, data from Waktu Solat (Teno Media) and Compass Android apps was not available for this phone model.

The Realme 3 Pro demonstrated excellent accuracy, with no deviations observed when using Easy Qiblat (Sun) and My-Solat (JAKIM) applications. However, when utilizing Easy Qiblat (Compass), Waktu Solat Malaysia (Murad Mohd Zain), Muslim Pro, and Al-Quran Melayu applications, deviations of less than 2°, less than 5°, less than 2°, and less than 6° were recorded, respectively. It is also important to note that data from Waktu Solat (Teno Media) and Compass Android applications were not available for this phone model.

Finally, the iPhone 7 Plus provided limited data as fewer applications were available for testing. Not all Android apps are available on iPhone due to the differing operating systems of iOS and Android. iOS devices like the iPhone can only run apps that are authorized by Apple. Only the Muslim Pro application could be tested on the iPhone 7 Plus, showing a deviation of less than 2°, whereas other applications did not provide data for analysis.

Based on the data provided in Table 2, an analysis of apps against the largest deviations in the Qibla direction can be plotted. Figure 6 provides a detailed depiction of the greatest deviation resulting from these apps.

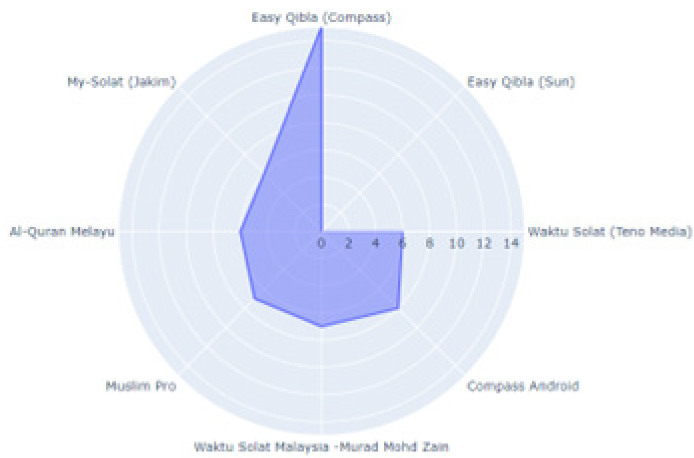

FIGURE 6. Analysis of the greatest deviations in various Qibla direction apps

The analysis of Qibla direction applications across various smartphone models reveals notable disparities in accuracy and consistency. Figure 6 displays the chart depicting the highest deviation among the applications. Among the apps examined, Easy Qiblat (Sun) stands out for its remarkable precision, consistently displaying zero deviations from the reference direction of 291° across multiple phone models. This reliability makes Easy Qiblat (Sun) a preferred choice for users seeking accurate Qibla direction without any discrepancies.

On the other hand, Easy Qiblat (Compass) exhibits varying levels of deviation, with the largest deviation exceeding 15°. While it performs relatively well on some models, where deviations are less than 8°, inconsistencies in accuracy are evident. The 15° deviation observed in the Xiaomi Redmi 4A could be attributed to the absence of a compass sensor in the phone. However, the lack of consistent large deviations when using the Xiaomi Redmi 4A with other apps makes it unclear whether there is a direct relationship between the compass sensor and the observed deviation.

The Waktu Solat (Teno Media) app also demonstrates variability, showing minor deviations of less than 1° on certain models but larger deviations exceeding 6° on others. On the other hand, the Compass Android app displays deviations ranging from 1° to less than 8° across different smartphone models. The Waktu Solat Malaysia by Murad Mohd Zain app exhibits significant variability in accuracy, with deviations ranging from greater than 3° to greater than 7° on various models.

Muslim Pro and Al-Quran Melayu apps also show deviations ranging from less than 0° to less than 7° and less than 0° to less than 6°, respectively, with varying accuracy across different smartphone models. However, limited data was available for analysis from the My-Solat (JAKIM) app, highlighting potential device compatibility issues across multiple phone models. This indicates that developers should modify their application software to ensure better compatibility with lower operating systems, aligning with the prevalent usage among the majority of people today as JAKIM is a federal government agency in Malaysia that administers Islamic affairs in Malaysia.

As stated in the 79th Muzakarah Jawatankuasa Fatwa Kebangsaan Bagi Hal Ehwal Ugama Islam Malaysia, held on September 6-8, 2007 (24-26 Sya'ban 1428 H), the permissible deviation (*Had al-Tahawwul 'Ani al-Qiblat*) for the Qibla direction in Malaysia is not more than 3° for the deviation of the mihrab. Thus, the use of applications such as Easy Qiblat (Sun) meets this requirement as it consistently shows a 0° deviation. However, other applications exhibit varying degrees of deviation, indicating that users need to carefully choose a good combination of smartphone and application to achieve a deviation below the 3° threshold as suggested in the

Muzakarah, particularly for travelers. Because of that, the most effective approach to determining the Qibla direction at home, work, or in a mosque is still through the utilization of a theodolite. Individuals or organizations can obtain services to verify the Qibla direction at their places by contacting either the mufti department in their region or agencies recognized and certified by the mufti department for Qibla determination. By utilizing these services, individuals can have the confidence and assurance of performing their prayers in accordance with the prescribed Qibla orientation.

ANALYSIS ON EASY QIBLAT (SUN)

From the above analysis, Easy Qiblat (Sun) emerges as the most reliable application for determining the Qibla direction, consistently showing zero-degree deviation across various smartphones. This superior accuracy is rooted in the method it employs, which relies on the position of the sun rather than a compass. This aligns with findings from Niri, Zaki, and Nor (2023), where the Sun Compass application also demonstrated high accuracy with deviations below 0.5°.

The principle behind Easy Qiblat (Sun) involves using the sun's position at specific times of the day to align with the Qibla direction. This method leverages the predictable and stable nature of celestial bodies, providing a high level of precision. Users align the shadow of an object with a reference line, which directly points towards the Qibla. This approach is inherently more accurate because it is based on astronomical calculations that are not influenced by environmental factors.

In contrast, applications that use a compass for Qibla direction can be significantly affected by various external factors. The accuracy of a compass is compromised by the presence of metal objects, electromagnetic fields, and other environmental interferences. Furthermore, prior studies on Qibla finder devices focused solely on optimal conditions, such as operating on flat surfaces, and did not address the significance of compass calibration (Tawil, 2023). These factors can cause the compass needle to deviate from the true magnetic north, leading to inaccurate readings. As a result, compass-based applications cannot provide consistent and reliable Qibla directions, which are not suitable for the precise requirements of religious practices.

The discrepancies observed in the study, particularly the ones that showed deviations greater than 3°, underscore the limitations of compass-based methods. Such deviations highlight the potential for significant errors, especially in environments with high metal content or electronic interference. This inconsistency makes compass-based applications less dependable for determining the Qibla direction.

Therefore, the Easy Qiblat (Sun) application stands out due to its independence from these environmental factors. By utilizing the sun's position, it offers a robust and consistent method for Qibla determination, ensuring that users can perform their prayers accurately regardless of their surroundings. This makes it the preferred choice for Muslims seeking a reliable tool for Qibla direction, reinforcing the importance of traditional astronomical methods in modern technological applications.

CONCLUSION

The study conducted at the East Coast Environmental Research Institute (ESERI) aimed to assess the accuracy of Qibla direction applications on smartphones using the *istiwa' adzam* method. The research addressed a crucial aspect for Muslims, especially those residing far from Mecca, where determining the Qibla direction presents significant challenges due to potential errors in smartphone applications.

The results obtained from the study revealed notable disparities in the accuracy and consistency of various Qibla direction applications across different smartphone models. The *istiwa' adzam* method consistently showed accurate Qibla directions, serving as a reliable reference point. However, several smartphone applications, including Easy Qiblat (Compass), Waktu Solat by Teno Media, Compass Android, Waktu Solat Malaysia by Murad Mohd Zain, Muslim Pro, Al-Quran Melayu, and My-Solat (JAKIM), exhibited deviations from the true Qibla direction.

Among the tested applications, Easy Qiblat (Sun) stood out for its remarkable precision, consistently showing zero deviations from the true Qibla direction across multiple smartphone models. This finding suggests that Easy Qiblat (Sun) can be a preferred choice for users seeking accurate Qibla direction without discrepancies.

On the other hand, applications such as Easy Qiblat (Compass), Waktu Solat by Teno Media, Compass Android, Waktu Solat Malaysia by Murad Mohd Zain, Muslim Pro, and Al-Quran Melayu showed varying levels of deviation, ranging from minor to significant discrepancies compared to the *istiwa' adzam* method. The analysis also highlighted potential device compatibility issues with the My-Solat (JAKIM) app and iPhone 7 Plus, as limited data was available for analysis across multiple smartphone models and applications.

In conclusion, the study emphasizes the importance of accuracy in Qibla direction applications for Muslims and suggests the need for reevaluation and improvement in the accuracy of these applications. The findings provide valuable insights for users in selecting dependable Qibla direction apps and offer recommendations for developers and smartphone companies to enhance the accuracy of their devices and applications in this aspect.

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AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conceptualization, methodology, data collection, data analysis, and writing of this paper. All authors reviewed and approved the final manuscript.

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