

## Digital Ijtihad in Determining the Direction of Qibla: Analysis of Accuracy and Limitations of Augmented Reality-Based Applications

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### Keywords:

Qibla Direction Measurement, Android Application, Augmented Reality Camera.

**Abstract:** Technological developments have given rise to more than 500 qibla direction measurement applications on Google Playstore, but validation of their accuracy in locations with specific geographical challenges, such as the mountainous topography of Baturraden, has been minimal. Moreover, visitors from outside the area often rely solely on the direction of the prayer mat and do not pay attention to the accuracy of the actual qibla direction. This study aims to analyze the accuracy of qibla direction measurements using Android applications with Augmented Reality (AR) camera technology in prayer rooms and mosques in the tourist location of Baturraden as a form of ijtihad to obtain legal certainty regarding the qibla direction. This study is a field study with a qualitative approach. Qibla direction measurements were taken at eight locations using five different applications: NU Online Super Apps, Duff Qibla Finder, Miqat, Kompas Kiblat (AR), and Arah Kiblat (AR). The results show that most applications performed well, with measurement differences between applications ranging from 0° to 1°, which is considered accurate according to Thomas Djamaludin's tolerance. However, the key finding of this study was the significant variation in performance and constraints. The Duff Qibla Finder application showed poor performance and did not refer to the correct qibla direction, as well as using a measurement scale of 65°-435°. In addition, the accuracy of the application was greatly influenced by environmental factors at the research location, such as degradation.

**Kata Kunci:**

Pengukuran Arah Kiblat,  
 Aplikasi Android,  
 Augmented Reality  
 Kamera.

**Abstrak:** Perkembangan teknologi telah melahirkan lebih dari 500 aplikasi pengukur arah kiblat di Google Playstore, namun validasi akurasi pada lokasi dengan tantangan geografis spesifik, seperti topografi pegunungan di Baturraden masih minim dilakukan. Terlebih bagi pengunjung luar daerah sering kali hanya mengandalkan arah hadap sajadah dan tidak mengindahkan ketepatan arah kiblat yang sesungguhnya. Penelitian bertujuan menganalisis akurasi pengukuran arah kiblat menggunakan aplikasi android berteknologi Augmented Reality (AR) kamera pada musala dan masjid di lokasi wisata Baturraden sebagai bentuk ijtihad untuk memperoleh kepastian hukum menghadap kiblat. Penelitian ini merupakan penelitian lapangan dengan pendekatan kualitatif. Pengukuran arah kiblat dilakukan pada delapan titik lokasi menggunakan lima aplikasi berbeda; NU Online Super Apps, Duff Qibla Finder, Miqat, Kompas Kiblat (AR), dan Arah Kiblat (AR). Hasil penelitian menunjukkan sebagian besar aplikasi memberikan performa yang baik, dengan selisih pengukuran antar aplikasi berkisar antara 0<sup>0</sup>-1<sup>0</sup>, yang dianggap akurat menurut toleransi Thomas Djamaludin. Namun, temuan kunci dari penelitian ini adalah adanya variasi kinerja dan kendala yang signifikan. Aplikasi Duff Qibla Finder menunjukkan performa yang kurang baik dan tidak merujuk pada arah kiblat yang tepat, serta menggunakan skala pengukuran 65<sup>0</sup>-435<sup>0</sup>. Selain itu, akurasi aplikasi sangat dipengaruhi oleh faktor-faktor lingkungan di lokasi penelitian, seperti degradasi sinyal GPS di area berbukit dan tertutup, gangguan medan magnet terhadap kalibrasi kompas di sekitar bangunan, dan human eror saat pengambilan data. Temuan ini tidak hanya mengonfirmasi bahwa aplikasi AR adalah alat praktis bagi pengguna awam, tetapi juga mengidentifikasi batasan-batasannya, sehingga menjadi panduan berharga bagi pengguna dan pengembang aplikasi.

## INTRODUCTION

Facing the qibla has been agreed upon by scholars as one of the valid requirements for performing prayer. For those who are far from the Kaaba, the obligation to face the qibla becomes an issue, because facing the Kaaba as required means facing the actual Kaaba.<sup>1</sup> This ruling refers to the words of Allah SWT in QS. Al-Baqarah: 144 which means: "...turn your face towards the Masjidilharam. And wherever you are, turn your face towards it ...". Based on this verse, it is clear that the

<sup>1</sup> Abd Karim Faiz, "Moderasi Fiqh Penentuan Arah Kiblat: Akurasi Yang Fleksibel," *JIL: Journal of Islamic Law* 1, no. 1 (2020): 83–99, <https://doi.org/10.24260/jil.v1i1.23>.

Masjidilharam or Ka'bah located in Mecca, Saudi Arabia, is the direction of the Qibla for Muslims.<sup>2</sup>

The obligation to face the Qibla is emphasized in the Qur'an and hadith. In the perspective of classical Fiqh Mawaqit, the determination of the direction of the Qibla is divided into two: *'Ainul Ka'bah* for those who are close, and *Jihatul Ka'bah* for those who are far away. Considering that the Baturraden tourist site is located thousands of kilometers from the Kaaba, what must be fulfilled is *Qiblatul Jihat*. The legal consequence is that there is leeway or tolerance in the angle of inclination, making the purpose of determining the Qibla to achieve *dzann* (strong presumption), not absolute certainty. Efforts that can be made include *ijtihad*, which can be performed by a Muslim, one of which is through a digital application approach, also known as *digital ijtiḥad*. This form of *ijtiḥad* also applies in determining the start of prayer times, *rukyatul hilal*, and so on. In the succession of *rukyatul hilal*, it is necessary to be certain that there are no obstacles, including rainfall.<sup>3</sup> Likewise, in the case of *rukyat* testimony given by women, it is considered invalid, even if they see the crescent moon directly.<sup>4</sup> All of these things are in order to obtain a strong assumption (*dzann*), including in determining the direction of the qibla with various methods, means, and adaptations to the development of science and technology.

With the advancement of science and technology today, the location of the Ka'bah in Mecca can be determined using smartphone technology through applications, information systems, or other digital platforms. The ease of access in measuring the direction of the qibla through digital platforms does not always provide the same and accurate results, so it is important to be able to sort out Android applications that provide high certainty in determining the direction of the qibla. On Google Playstore, there are more than 500 applications that provide qibla direction measurement services with various combinations of technologies, such as compass sensors, GPS, regional maps, and the most advanced technology, namely Augmented Reality camera technology.

In the contemporary era, determining *the qibla* is achieved through "Digital Ijtihad," which involves the use of advanced devices like AR apps that integrate GPS and geomagnetic sensors. The presence of this technology is a form of facilitating sharia (*tashil as-syar'i*). However, Fiqh principles state that the ruling on the means

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<sup>2</sup> Fakhri Muttaqien et al., "Studi Penentuan Arah Kiblat dan Koreksi Arah Kiblat Menggunakan Kompas Digital Dan Gps Berbasis Microcontroller Arduino," *Prosiding Seminar Nasional Fisika (SiNaFi)*, no. 105 (2018): 271–75. <https://pdfcoffee.com/prosiding-seminar-nasional-fisika-sinafi-vol-4-no-1-2018-2-pdf-free.html>

<sup>3</sup> Machzummy, "Pengaruh Curah Hujan Terhadap Keberhasilan Rukyat Hilal Pada Observatorium Lhoknga Aceh," *Samarah* 3, no. 1 (2019): 223–39, <https://doi.org/10.22373/sjhc.v3i1.5061>.

<sup>4</sup> Machzummy Machzummy and Badrun Taman, "The Role Of Women In The Rukyat Hilal According To The North Aceh Ulema Consultative Assembly," *Jurnal Ilmiah Mizani: Wacana Hukum, Ekonomi, Dan Keagamaan* 09, no. 02 (2022): 176–85, <https://doi.org/10.29300/mzn.v9i2.2915>

(*wasilah*) depends on its purpose.<sup>5</sup> Therefore, *the* accuracy of this tool must be validated, especially in difficult locations, to ensure that *the dzann* produced is strong and tested. Moreover, with the increasingly sophisticated development of applications, users are required to be more selective in determining which applications are capable of providing the strongest *dzann*.

The use of *Augmented Reality* (AR) camera technology is found in several Android applications, such as NU Online, Miqat, Duff Qibla Finder, and Qibla Direction. This technology has become popular because it provides a visual reality display that gives more stability. However, the use of Android applications on different smartphone brands and models can produce different measurements. Moreover, application performance can be disrupted by other external factors. Therefore, according to the author, it is important to test the accuracy and precision of Android applications that measure the direction of the qibla using *Augmented Reality* camera technology to compare them with conventional methods.

Studies related to Android applications using *Augmented Reality* technology are still relatively new, even though this technology has already been utilized in other fields, such as mathematics education,<sup>6</sup> engineering,<sup>7</sup> musical instruments<sup>8</sup>, and so on. The development of this technology in qibla direction applications can also be found in the Miqat application researched by Nuafal Faza Muttaqin<sup>9</sup> which focuses on accuracy by considering the Earth's spherical and ellipsoidal shape. However, it does not show the practical side, limitations, or accuracy with other applications. Other studies related to applications have also been conducted, including Fajar Fathurrahman<sup>10</sup>, which shows the "practical" side of measuring the direction of the

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<sup>5</sup> Arwin Juli Rakhmadi Butar-Butar, *Pengantar Ilmu Falak: Teori, Praktik Dan Fikih*, ed. Arwin Juli Rakhmadi Butar-Butar, 1st ed. (Depok: Rajagrafindo Persada, 2018).

<sup>6</sup> Adam Syahrul, Syarli, and Cipta Riang Sari, "Penerapan Teknologi *Augmented Reality* Pada Media Pembelajaran Berbasis Android," *Journal Pegguruang: Conference Series* 4, no. 1 (2022): 1, <https://doi.org/10.35329/jp.v4i1.2828>.

<sup>7</sup> Markho I. Maramis, Arie S. Lumenta, and Brave A. Sugiarto, "Augmented Reality Pada Aplikasi Android Memperlihatkan Gedung Fatek," *E-Journal Teknik Elektro Dan Komputer* 5, no. 1 (2016): 40–48. <https://doi.org/10.35793/jtek.v5i1.11542>

<sup>8</sup> Tri Mulyadi, Muhammad Rizal H, and Amran Amiruddin, "Penerapan Teknologi *Augmented Reality* Sebagai Sarana Edukasi Perkenalan Alat Musik Dengan Metode Single Marker," *Journal of Information System Management (JOISM)* 1, no. 2 (2020): 18–21, <https://doi.org/10.24076/joism.2020v1i2.26>.

<sup>9</sup> Naufal Fazal Muttaqin, "The Utilization Of *Augmented Reality* Technology In Determining Qibla Direction (Analysis Of Miqat Applications By Samer Joudi)," *Al-Hilal: Journal of Islamic Astronomy* 5, no. 1 (2023): 1–28. <https://doi.org/10.21580/al-hilal.2023.5.1.13734>

<sup>10</sup> Fajar Fathurrahman, "Learning Innovation of Qibla Direction with Mobile-Based App by Adapting Computational Thinking," *Jurnal Iqra'-Kajian Ilmu Pendidikan* 6, no. 1 (2020): 211–24, <https://doi.org/https://doi.org/10.25217/ji.v6i1.981>.

qibla with an application. Miftahul Jannah Ami and Ifrohati<sup>11</sup> studied the Miqat application for measuring mosques. Furthermore, no other studies discussing Android applications for measuring the direction of the qibla have been based on the use of AR technology. In this context, with the increasing number of AR-based applications, it is necessary to conduct an in-depth study, especially for people who tend to prefer practical and accurate solutions.

Someone who is in a new location will experience confusion in determining the direction, especially the direction of the qibla. This is the case at the Baturraden tourist site, located on the slopes of Mount Slamet, where the winding roads and sloping topography often make it difficult for visitors from outside the area to determine the direction of the qibla. In addition, at most tourist sites, the prayer areas provided are only square-shaped buildings, and the qibla direction is only indicated by the direction of the prayer mats already available inside. The prayer areas provided there often do not take into account the accuracy of the qibla direction. Visitors from outside the area will naturally follow the direction of the prayer mats and ignore the accuracy of the qibla direction. Therefore, there is an urgent need to validate the reliability of AR applications in specific and challenging environments such as this. The accuracy of AR applications can be a quick and practical solution to help guide visitors in determining the correct and reliable qibla direction, especially those that provide visual reality features.

AR technology allows users to see the direction of the qibla directly through their smartphone cameras with the help of visuals displayed as an overlay on the real view on the screen. This allows users to obtain the direction of the qibla with high accuracy using only one device that they always carry, namely a smartphone. The urgency of using AR technology in measuring the direction of the qibla is increasing with the increasing mobility of the community, whether for business trips, tourism, or other activities. AR technology is claimed to provide ease of access and measurement precision that is difficult to achieve with manual methods, especially in new locations that may not have clear signs of the direction of the qibla. This study uniquely and comprehensively compares and analyzes the performance of five AR qibla direction applications in the same location, namely the Baturraden tourist attraction. This can help users choose and use the application that suits their needs and preferences. Unlike previous studies, Naufal Faza Muttaqin (2019) focused on one Miqat application, Gunawan (2021) focused on compasses on smartphones<sup>12</sup>, and Samsudin, Kusdiyana,

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<sup>11</sup> Miftahul Jannah Ami and Ifrohati Ifrohati, "Miqat Application in Determining the Qibla Direction of the Mosque," *Nurani: Jurnal Kajian Syari'ah Dan Masyarakat* 22, no. 1 (2022): 121–32, <https://doi.org/https://doi.org/10.19109/nurani.v%vi%.11798>.

<sup>12</sup> Gunawan Gunawan and Nur Asiyah, "Akurasi Kompas Digital Pada Smartphone Android Dalam Penentuan Arah Kiblat," *Hisabuna* 2, no. 3 (2021): 1–32, <https://doi.org/10.24252/hisabuna.v2i2.17177>

and Rizal Ramadhan (2021) focused on supermarket prayer rooms.<sup>13</sup> This study critically investigates the impact of real environmental factors such as GPS signal interference, local magnetic fields, and physical building conditions on measurement accuracy. This analysis provides a deeper understanding of the limitations and potential of AR applications in a practical context.

## RESEARCH METHOD

This research is a field study using a qualitative approach that places the researcher as the subject of the study, as well as the main instrument that reveals the accuracy of qibla direction measurements using an Android application with Augmented Reality camera technology. The research location was at the Baturraden tourist attraction, which had 373,743 visitors in 2023, predominantly from outside the region. There are box-shaped prayer rooms, and not all of them have qibla direction indicators. The research location was chosen at the Baturraden tourist area's " " due to its specific and challenging characteristics, including the slope contour, the number of buildings, and visitors who are predominantly tourists from outside the region. The research data sources came from primary and secondary sources. Primary sources were obtained through observations in the form of qibla direction measurements using five Android applications, namely NU Online, Duff Qibla Finder, Miqat, and Kompas Kiblat (AR). Secondary data was collected through relevant documentation techniques such as books and journals. Data analysis was carried out in stages, starting from data reduction, data presentation, and conclusion drawing. The results of the qibla direction measurements were compared with each application, the azimuth/qibla angle values on the compass in the application, and the direction of the buildings/prayer rows in the prayer rooms and mosques at the Baturraden tourist site. The data obtained were correlated with each other by referring to spherical trigonometry theory, and conclusions were drawn.

## RESULTS AND DISCUSSION

### Qibla Direction and the Development of Qibla Direction Measurement Methods

The qibla direction is one of the valid requirements for performing prayer. This requirement is based on the strong belief that a *person praying* is truly facing the qibla. This is emphasized in the words of Allah SWT in Surah Al-Baqarah Verse 144:

قَدْ نَرَى تَقَلُّبَ وَجْهِكَ فِي السَّمَاءِ فَلَنُوَلِّيَنَّكَ قِبْلَةً تَرْضَاهَا فَوَلِّ وَجْهَكَ شَطْرَ الْمَسْجِدِ الْحَرَامِ ۗ وَحَيْثُ مَا كُنْتُمْ فَوَلُّوا وُجُوهَكُمْ شَطْرَهُ ۗ وَإِنَّ الَّذِينَ أُوتُوا الْكِتَابَ لَيَعْلَمُونَ أَنَّهُ الْحَقُّ مِنْ رَبِّهِمْ ۗ وَمَا اللَّهُ بِغَافِلٍ عَمَّا يَعْمَلُونَ ۙ ١٤٤

*"Indeed, We see you (Prophet Muhammad) often turning your face toward the sky. So We will surely turn you toward a direction that pleases you. Then turn your face*

<sup>13</sup> Samsudin Samsudin, Kusdiyana Kusdiyana, and Rizal Ramadhan, "Accuracy Test of Supermarket ' S Mushola Qibla Direction," 8, no. 2 (2021): 171–88. <http://dx.doi.org/10.29300/mzn.v8i2.2797>

toward the Sacred Mosque. Wherever you are, turn your faces toward it. Indeed, those who have been given the Book know that it is the truth from their Lord. Allah is not unaware of what they do." (Q.S. Al-Baqarah: 144)

In the narration about the reason for the revelation of the above verse, the Prophet Muhammad SAW really wanted Allah to set the qibla towards the Ka'bah. Therefore, he often raised his face to the sky, waiting for the revelation that would command the change of the qibla. Then, this verse was revealed, establishing the change of the qibla from Baitulmakdis to Masjidilharam. Here, the direction of the Sacred Mosque is mentioned, not the Ka'bah, as an indication that allows us to face "towards the Ka'bah" during prayer. If the Ka'bah is far away from us and cannot be seen. Conversely, if we are close to the Kaaba, then we face the Kaaba during prayer.<sup>14</sup> So it is not obligatory to face the Kaaba building, except for those who can see it. Thus, all Muslims in various parts of the world are required to face "towards the Kaaba" during prayer. This command is an important basis for determining the direction of the qibla using with the term *Syatral Masjid Al-Haram*.<sup>15</sup> The meaning of *syathr* is also the basis for determining the direction or direction of the qibla for those who use *jihah al Qiblah*.

The belief in facing the qibla in the context of the above fiqh scholars is referred to as '*ainulka'bah* or *qiblatulyaqin*. Scientifically, the direction of the qibla is proven by the existence of the Kaaba or Masjidilharam. However, for those who are around Mecca but are unable to see the Kaaba or Masjid al-Haram, efforts must be made to estimate (*dzann*) the exact location of the Kaaba or Masjid al-Haram.<sup>16</sup> Most scholars are of the opinion that people who are unable to see the physical structure of the Kaaba are required to face the direction of the Kaaba by facing the place of prayer that indicates the direction of the Kaaba or based on *ijtihad* or by asking someone who is trustworthy and considered an expert in determining the direction of the qibla, and if it is only based on conjecture, then it is permissible to follow it on the condition that the time for prayer is short. Imam Asy-Syafi'i, quoted by Adhiyah Syam, states that if someone cannot determine the direction of the qibla, then he may use *ijtihad* in a way that is considered closest to the direction of the qibla, and his prayer is still valid.<sup>17</sup> The

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<sup>14</sup> Subehan khalik Nur Amalia, Muh. Rasywan Syarif, "Toleransi Kemelencengan Arah Kiblat," *Hisabuna* 4, no. 1 (2023): 109–22. <https://doi.org/10.24252/hisabuna.v4i1.35802>

<sup>15</sup> Abd Salam Nawawi, *Ilmu Falak Cara Praktis Menghitung Waktu Salat, Arah Kiblat Dan Awal Bulan*, ed. Abd Salam Nawawi, *Aqaba*, (Sidoarjo: Aqaba, 2010).

<sup>16</sup> Tasliyah Erlina, Saleh Ridwan, and Kurniati, "Urgensi Kementerian Agama Kabupaten Barru Dalam Menentukan Standar Dan Validasi Arah Kiblat," *HISABUNA: Jurnal Ilmu Falak* 3, no. 2 (2022): 101–27, <https://doi.org/10.24252/hisabuna.v3i2.22912>.

<sup>17</sup> Subehan Khalik Himatul Adhiyah Syam, "Harmonisasi Intrumen Arah Kibat," *Jurnal Ilmiah Mizani: Wacana Hukum, Ekonomi, Dan Keagamaan* 1 (2020), <https://doi.org/10.24252/hisabuna.v1i1.13114>

method of determining the direction of the qibla that has developed today is a product of the ijtihad of scholars.<sup>18</sup>

As a form of ijtihad, the method of determining the direction of the qibla can evolve in accordance with the changing times. This is not denied by the scholars, as changes in the law occur due to changes in customs, changes in the interests of humanity, and in emergency situations.<sup>19</sup> A person who does not know the qibla and is uncertain about its direction, and there is no one who can be trusted to inform him about the direction of the qibla with certainty and clarity, is obliged to conduct research and ijtihad. That is, to try as hard as possible to find out the direction of the qibla with convincing evidence. If there is someone trustworthy who can inform them about the direction of the qibla with certainty, then they are obliged to follow the information provided by that person. This is because the information of someone who knows the direction of the qibla is stronger than ijtihad.<sup>20</sup>

In today's digital age, information related to the direction of the qibla can be easily accessed through applications and various methods that are believed to provide accurate information about the direction of the qibla. To ensure the accuracy of the direction of the qibla, more than one method can be used to confirm the correct direction. The compass method can be combined with the sun shadow method or GPS application to obtain more accurate results. This approach ensures that the determined qibla direction is truly accurate and in accordance with Islamic law.<sup>21</sup> The right-angle triangle method is based on basic trigonometry principles, where the qibla direction is calculated based on the geographical coordinates of the location and the coordinates of the Kaaba in Mecca.<sup>22</sup> The *Rashdul* qibla method is a condition where all shadows of objects at a certain time face the Kaaba when exposed to sunlight. *Rashdul* kiblat is divided into two types, namely daily *rashdul* kiblat and annual *rashdul* kiblat.<sup>23</sup> The astronomical method involves the use of astronomical instruments such as a theodolite or astrolabe to determine the direction of the qibla. This method is very accurate

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<sup>18</sup> Muthmainnah Muthmainnah and Fattah Setiawan Santoso, "Pemanfaatan Sains Dan Teknologi Dalam Pengukuran Arah Kiblat Di Indonesia," *Ulumuddin : Jurnal Ilmu-Ilmu Keislaman* 10, no. 2 (2020): 149–62, <https://doi.org/10.47200/ulumuddin.v10i2.441>.

<sup>19</sup> Zuhaili, Wahbah Al. *Fiqih Islam Wa Adillatuhu, Volume I*. 1st ed. Lebanon: Darul Fikr-Gema Insasni, 2010 p.121)

<sup>20</sup> Zuhaili, Wahbah Al. *Fiqih Islam Wa Adillatuhu, Volume I ...* p. 122

<sup>21</sup> Astuti Astuti, Fahmi Fatwa, and Encep Abdul, "Akurasi Arah Kiblat Pada Bangunan Bertingkat," in *Bandung Conference Series: Islamic Family Law*, ed. Astuti Astuti (Bandung, 2023), 68–74, <https://doi.org/https://doi.org/10.29313/bcsifl.vi.9380>.

<sup>22</sup> Ismail Ismail, "Standar Operasional Prosedur (SOP) Kalibrasi Arah Kiblat Masjid Di Era Digital," *Al-Marshad: Jurnal Astronomi Islam dan Ilmu-Ilmu Berkaitan* 5, no. 1 (2019): 90–110, <https://doi.org/10.30596/jam.v5i1.3126>.

<sup>23</sup> Juli Arwin; Rakhmadi and Hasrian Rudi Setiawan, "Pemanfaatan Instrumen Astronomi Klasik Mizwala Dalam Pengukuran Dan Pengakurasian Arah Kiblat," *Maslahah Jurnal Pengabdian* 1, no. 1 (2020): 49–58, <https://doi.org/10.30596/maslahah.v>.

because it is based on the position of stars or other celestial objects that are used as references in measurements.<sup>24</sup>

### The Work Process of Augmented Reality Applications

Ijtihad in the present day can be realized through the updating of digital products that are able to provide legal certainty for Muslims in fulfilling the requirements of *digital ijtihad* worship, such as certainty of the start time of prayer and the direction of the qibla. This update is reinforced in terms of the working process of a digital tool or application that can be understood by the general public. The workflow for Android applications that utilize AR technology is basically the same as other qibla direction applications. However, AR-enabled applications have additional performance on the gyroscope and accelerometer to capture continuous data updates taken from the device's camera and sensors.<sup>25</sup> The workflow is as follows:

#### 1. Sensor Data Collection

The AR Android application for measuring the direction of the qibla relies on several sensors found on smartphone devices, namely the camera sensor, compass, gyroscope, accelerometer, and GPS.

#### 2. Sensor Data Calibration and Synchronization

Before starting the measurement, the application calibrates the sensors to ensure accuracy. The compass needs to be calibrated to avoid magnetic interference. Data from the gyroscope and accelerometer are also synchronized to provide accurate device orientation.

#### 3. Location and Direction Data Processing

The application requests to activate GPS to determine the user's geographical coordinates. The application system also contains the coordinates of the Kaaba in Mecca, which are stored in the application database. The application calculates the angle of the Qibla based on the difference between the user's coordinates and the coordinates of the Kaaba. Trigonometric algorithms or haversine formulas are used to calculate the exact distance and direction.

#### 4. Use of AR Technology

The application uses the camera to display real-world images. On top of these images, the application displays a virtual overlay showing the direction of the qibla. When the user moves the device, the application continuously updates the sensor data to keep the qibla direction accurate. The gyroscope and accelerometer help adjust the qibla direction display according to the device's orientation.

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<sup>24</sup> Yusuf Somawonata, *Ilmu Falak: Pedoman Lengkap Waktu Salat, Arah Kiblat, Perbandingan Tarikh, Awal Bulan Qamariah, Dan Hisab Rukyat*, ed. Monalisa, (Depok: Grafindo Persada, 2020).

<sup>25</sup> Nurul Bahiyah, Petrus Sokibi, and Imam Muttaqin, "Aplikasi Pengenalan Produk Menggunakan Augmented Reality Dengan Metode Marker," *Jurnal Sistem Cerdas* 3, no. 3 (2020): 184–91, <https://doi.org/10.37396/jsc.v3i3.89>.

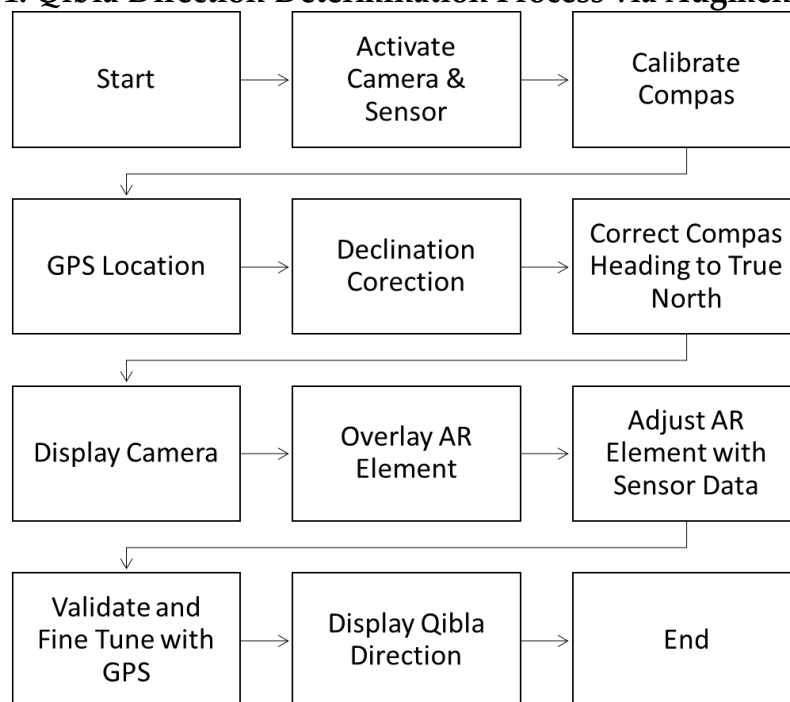
## 5. Qibla Direction Visualization

The direction of the qibla is displayed as a line or arrow pointing to the Kaaba above the camera image. Some applications may also display a small map showing the direction of the qibla relative to the user's position. The application uses Augmented Reality (AR) by adding elements such as a 3D compass, directional guide, or Kaaba icon that moves according to the movement of the device.

Here is an explanation of each step in running an Augmented Reality application to determine the qibla direction, as follows:

- a. Start: Begin the application process.
- b. Activate Camera and Sensors: Enable the camera and necessary sensors (compass, gyroscope, accelerometer, GPS).
- c. Calibrate Compass (Magnetometer): Calibrate the compass (magnetometer) to ensure directional accuracy.
- d. Gather GPS Location: Collect the user's location data using GPS.
- e. Calculate Declination Correction: Calculate the magnetic declination correction based on the user's location.
- f. Correct Compass Heading to True North: Correct the compass heading to show true north.
- g. Display Real-Time Camera Feed: Display the camera feed in real time.
- h. Overlay AR Elements for Qibla Direction: Add AR elements (such as arrows or lines) to indicate the direction of Qibla on top of the camera feed.
- i. Adjust AR Elements with Sensor Data: Adjust AR elements according to data from sensors (gyroscope and accelerometer) to maintain accuracy.
- j. Validate and Fine-Tune with GPS: Validate and refine the qibla direction with GPS data if necessary.
- k. Display Qibla Direction: Display the corrected and stabilized qibla direction.
- l. End: Process complete.

The following image illustrates the workflow of an Augmented Reality (AR)-based qibla application, namely the stages of how the application determines and displays the qibla direction accurately with the help of a camera, sensors, and GPS. This is illustrated more clearly in the image below:

**Figure 1. Qibla Direction Determination Process via Augmented Reality**

Source: Augmented Reality

The figure above explains the technical mechanism of how the AR Qibla application works from start to finish, displaying the accurate and real-time qibla direction by combining the camera, sensors, and GPS.

### **Qibla Direction Measurement for Mosques and Prayer Rooms at Baturraden Tourist Attraction**

Generally, the operation of the AR Qibla direction application involves integrating data from various smartphone sensors, including GPS, compass, gyroscope, and accelerometer. However, some applications present a more practical process, such as the Qibla Direction (AR) application. GPS determines the user's geographical coordinates, which are then used to calculate the Qibla direction angle relative to the Ka'bah. The practical values provided make it easier for users to operate the application. Users only need to activate data network access, permissions, , and access to the smartphone's location and camera, then run the application and select the qibla direction menu, then point the smartphone in the direction of the qibla indicated on the application. The digital compass functions to determine the wind direction and qibla direction, while AR technology displays a virtual arrow or line pointing to the Kaaba on top of the real-time camera image.

Measurement results at 8 locations in the Baturraden tourist area show that most applications provide consistent results. There is a difference in values between applications of  $0^0-1^0$ , which is still within the acceptable accuracy limit.

**Table 1. Qibla Direction Measurements Using Augmented Reality Applications**

No	Musholla/Tempat Sholat	Arah Kiblat Aplikasi (AR)				
		NU Online Super Apps	Miqat	Kompas Kiblat	Arah Kiblat (AR)	Duff Qibla Finder
1	Masjid Jami' As-Syafir	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
2	Musholla As-Salam	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
3	Masjid Indraparna	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
4	Musholla Kolam Renang	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
5	Musholla Sepeda Air	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
6	Musholla Pancuran 3	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
7	Musholla Al Barokah (Exit 2)	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil
8	Musholla Parkir 2	Angka tidak tampil	Angka tidak tampil	294,7°	65°43'	Angka tidak tampil

Source: Data processed by the author, 2025.

The qibla direction measurement values displayed on the applications varied. Only the Qibla Compass and Qibla Direction (AR) applications displayed numerical values. To determine the qibla angle values for comparison, calibration was performed by comparing the measurement results with the qibla compass values on each application. The NU Online Super Apps application was calibrated with the qibla direction value on the qibla compass feature of the application, which showed a value of 294°36'. The NU Online Super Apps and Miqat applications performed well, as did the Qibla Compass (AR) and Qibla Direction (AR) applications, which displayed practical displays.

The most notable finding of this study was the performance of the Duff Qibla Finder app. Unlike other apps that consistently display numbers, Duff Qibla Finder performed poorly and did not refer to the correct qibla direction. Further analysis revealed that this app uses an unusual measurement scale, namely 65°-425°, which differs from the common 360° standard. The above data adjustments can be converted into qibla azimuth values according to UTSB as follows:

**Table 2. Alignment of Qibla Azimuth from the Qibla Direction Measurement Application**

No	Musholla/Tempat Sholat	Arah Kiblat Aplikasi (AR)				
		NU Online Super Apps	Miqat	Kompas Kiblat (AR)	Arah Kiblat	Duff Qibla Finder
1	Masjid Jami' As-Syafir	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
2	Musholla As-Salam	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
3	Masjid Indraparna	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
4	Musholla Kolam Renang	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
5	Musholla Sepeda Air	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
6	Musholla Pancuran 3	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
7	Musholla Al Barokah (Exit 2)	294°36'	294° 52' 10,96"	294°11'	294°17'	295°
8	Musholla Parkir 2	294°36'	294° 52' 10,96"	294°11'	294°17'	295°

Source: Data processed by the author, 2025.

### The Influence of the Environment on the Accuracy of Augmented Reality Android Applications as a Form of Ijtihad Qiblatul Yaqin

The use of AR technology has a high level of accuracy, as seen in the Miqat application, which shows that there is a difference in measurement results between the spherical and ellipsoidal concepts of the Earth. However, this difference is relatively small and indicates a high level of accuracy.<sup>26</sup> In addition, each application has other advantages in terms of practicality and accuracy, such as the qibla compass, digital compass, and those that use visuals.<sup>27</sup> The use of qibla direction applications requires a high level of precision and sensitivity from smartphone devices, especially GPS and compasses, as the main components in optimizing the use of the application. The use of AR technology can be further developed to optimize the performance of the application in order to provide convenience, practicality, and confidence for service users.<sup>28</sup>

AR applications perform by combining data from various sensors in smartphones. The main elements that affect the accuracy and precision of AR applications are: 1) Global Positioning System (GPS), which determines the user's location with an accuracy of up to several meters. The application uses these

<sup>26</sup> Naufal Fazal Muttaqin, "Uji Akurasi Penentuan Arah Kiblat Menggunakan Aplikasi Android Berteknologi Augmented Reality (Study Analisis Aplikasi Miqat Karya Samer Joudi)," *Jurusan Ilmu Falak Fakultas Syariah Dan Hukum UIN Walisongo Semarang* (UIN Walisongo Semarang, 2019).

<sup>27</sup> M F Mohd Fauzi, N Nasir, and H Rashid, "Development of Qiblat Finder Assisted Device for Visual and Hearing-Impaired Persons," *Malaysian Journal of Ergonomics* 5, no. December (2023): 21–27. <https://doi.org/10.58915/mjer.v5i1.364>

<sup>28</sup> Shervin Minaee, Xiaodan Liang, and Shuicheng Yan, "Modern Augmented Reality: Applications, Trends, and Future Directions," 2022.

coordinates to calculate the direction of the Kaaba based on the user's relative position to the Kaaba in Mecca. 2) Digital Compass: The digital compass in the smartphone's provides features for determining wind direction and qibla direction. For accurate results, the compass must be properly calibrated, as the surrounding magnetic field can affect the sensor. 3) Augmented Reality (AR) Technology: AR technology allows users to see a visualization of the qibla direction displayed directly on the phone screen, combined with the physical environment view through the camera.

The presence of measurement discrepancies between applications indicates the need for adjustments to the devices used for determining the qibla direction. Although the differences between applications are small, this study successfully identified external factors contributing to these deviations, which is the core novelty of this article. The external factors obtained from qibla direction measurement data at the mosque in Lokaswisata Baturraden are:

a. GPS Accuracy Level

Under ideal conditions, GPS can provide location accuracy of up to 3-5 meters. In locations such as Baturraden, which is located on a mountain, there are many trees and buildings, which can interfere with or weaken the GPS signal, resulting in reduced accuracy. The measurements were taken inside buildings, which resulted in discrepancies in the measurement results. More open locations, such as the Al-Barokah mosque, the swimming pool mosque, and the water bike mosque in Baturraden, tend to provide more accurate measurement results. The accuracy of the qibla direction can theoretically be affected by errors in the measurement of geographical coordinates. GPS signal degradation, especially in closed or hilly areas, can cause differences in the qibla direction generated by the AR application.

b. Compass Sensor Calibration

Deviations or discrepancies in the measurements of mosques and prayer rooms in the Baturraden tourist area may also be due to problems with the calibration of the magnetic compass sensor on the smartphones used. These problems may include magnetic corrections for locations in mountainous areas and the structure of prayer rooms and mosques with larger iron loads. The difference in qibla direction values indicates that the magnetic sensor, when the application is running, such as on NU Online Super Apps, Miqat, Kompas Kiblat, Duff Qibla Finder, and Arah Kiblat (AR), shows movement in the qibla direction reference point, indicating an issue with the compass sensor, although not significant.

c. Environmental Conditions

The environmental conditions in Baturraden, with its many buildings and rocks, contribute to slowing down the AR application. This is confirmed by the *overlay* duration on the application, which shows a longer period of stable qibla direction accuracy. The environmental conditions in the Pancuran 3

mosque valley are surrounded by rocky cliffs and far from the center of the Baturraden tourist area. GPS and internet signals are constrained and take longer to respond to the application ( ), which impacts the stability of the qibla direction display.

d. Human Error

This condition was caused by data collection being carried out on weekends, when the location was busier and more crowded than on other days. Rushed data collection was a factor in the lack of accuracy in the use of the application. The author himself realized the involvement of this *human error* factor, especially after approaching prayer time, so that data collection was not optimal.

The analysis results show that efforts to determine the ease and practicality of the application in providing accurate information about the direction of the qibla are acceptable. The use of an Android-based Augmented Reality application to measure the direction of the qibla in mosques and prayer rooms in the Baturraden tourist area generally provides fairly accurate results. Under ideal conditions, with a strong GPS signal and proper compass calibration, the AR application is able to display the direction of the qibla with a very small deviation of less than 1 degree. However, several factors such as magnetic field interference, weak GPS signals, lack of compass calibration, and *human error* can reduce the level of accuracy. The results of this study indicate that the application can practically assist in indicating the qibla direction with very small deviation and is considered accurate.

## CONCLUSION

The use of an Android application with Augmented Reality technology to measure the direction of the qibla at the Baturraden tourist site shows fairly accurate and reliable results for use by the general public. A measurement difference of  $0^0 - 1^0$  confirms that this application can be a practical and modern tool to help Muslims worship, especially in unfamiliar locations. However, this study also identified that the accuracy of the application is greatly influenced by external factors specific to the location, including GPS accuracy, compass sensor calibration, environmental conditions, and human error. These findings reinforce the argument that although AR technology offers convenience, it has limitations that need to be considered. For measurements that require a very high level of precision, especially in areas that are difficult to access or enclosed, the use of traditional methods or special qibla measuring tools is still necessary as a means of verification. This study makes an important contribution by validating the usefulness of AR applications while providing a critical analysis of their limitations in challenging environments. Users of qibla direction measurement applications are advised to ensure the geographical conditions, GPS accuracy, compass sensor, and *human error*. This paves the way for further research that can compare this application with conventional methods in other locations with

different geographical conditions, to enrich the scientific literature in the field of astronomy and technology.

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