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DIGITAL VS TRADITIONAL QIBLA: QIBLA DIRECTION ACCURACY USING ISTIWA STICKS AND METAVERSE

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Abstract
This study evaluates the accuracy of Qibla direction using two different methods, namely the traditional method with istiwa sticks and the digital method based on Metaverse technology. The study was conducted on three randomly selected mosques in Indonesia. The study aims to compare the accuracy of Qibla direction measurements using the two approaches in order to provide further insights for the Muslim community in determining the appropriate Qibla direction. Primary data were collected through direct observation and field experiments in each mosque, which included measurements using istiwa sticks at specific times according to the position of the sun as well as Metaverse technology-based measurements integrating real-time astronomical data. The results showed significant differences between the two methods, with the digital method offering higher accuracy in certain situations, but the traditional method remaining relevant in the context of simple and accessible manual measurements. The study suggests more in-depth development of digital-based technologies and collaboration between technology scientists and fiqh experts to ensure the validity of Qibla direction determination in the digital age.
Keywords: *Qibla Direction, Istiwa Stick, Metaverse, Digital Technology, Qibla Measurement*

Abstrak
Penelitian ini mengevaluasi keakuratan arah kiblat menggunakan dua metode yang berbeda, yaitu metode tradisional dengan tongkat istiwa dan metode digital berbasis teknologi Metaverse. Studi ini dilakukan pada tiga masjid yang dipilih secara acak di Indonesia. Penelitian bertujuan untuk membandingkan keakuratan pengukuran arah kiblat menggunakan kedua pendekatan tersebut dalam rangka memberikan wawasan lebih lanjut bagi komunitas Muslim dalam menentukan arah kiblat yang sesuai. Data primer dikumpulkan melalui observasi langsung dan eksperimen lapangan di setiap masjid, yang mencakup pengukuran menggunakan tongkat istiwa pada waktu tertentu sesuai dengan posisi matahari serta pengukuran berbasis teknologi Metaverse yang mengintegrasikan data astronomi real-time. Hasil penelitian menunjukkan perbedaan signifikan antara kedua metode, dengan metode digital menawarkan keakuratan yang lebih tinggi dalam situasi tertentu, namun metode tradisional tetap relevan dalam konteks pengukuran manual yang sederhana dan dapat diakses. Studi ini menyarankan pengembangan teknologi berbasis digital yang lebih mendalam dan kolaborasi antara ilmuwan teknologi dan ahli fiqh untuk memastikan validitas penentuan arah kiblat di era digital.
Kata Kunci: Arah Kiblat, Tongkat Istiwa, Metaverse, Teknologi Digital, Pengukuran Kiblat

INTRODUCTION

Qibla direction determination is an important aspect in the implementation of Muslim worship,[1] especially in establishing prayer[2]. . Qibla refers to the direction of the Kaaba in Mecca which is the point of orientation for Muslims around the world.[3] Along with the development of science and technology[4], the method of determining the Qibla direction has undergone various changes. In the past, Muslims used simple methods such as the istiwa stick[5], compass[6], to the shadow of the sun to ascertain the Qibla direction.[7] However, today, the development of digital technology has offered a new alternative by using satellite map-based applications and virtual reality technologies such as Metaverse.[8] This development raises questions regarding the accuracy and validity of both methods, especially in the context of the relationship with Islamic law (fiqh).

The istiwa stick, which is a traditional method of determining the Qibla direction, has been used for centuries by Muslims in various parts of the world.[9] This method utilizes the movement of the sun's shadow at certain times to determine the Qibla direction. The reliability of the istiwa stick as a Qibla determination tool is considered very high, especially in favorable environmental conditions, because this method is directly related to the position of the sun as a stable astronomical object[10]. However, this method also has weaknesses, especially related to the limited time of its use which is only effective at

[1] W. S. Mada Sanjaya et al., "The Third Al-Biruni's Method for The Determination of Qibla Direction from Kitab Tahdid Nihayat Al-Amakin with The Implementation Based on Arduino Board MCU, GPS Module, and Digital Compass," in *2019 International Seminar on Research of Information Technology and Intelligent Systems (ISRITI)* (IEEE, 2019), 403–8, https://doi.org/10.1109/ISRITI48646.2019.9034634.

[2] Mursyid Fikri, *Modul Pembelajaran Ilmu Falak Bagian 1*, 1st ed. (Makassar: LPP Unismuh Makassar, 2020). 46

[3] W. S. Mada Sanjaya et al., "Implementation of Ibn Al-Haytham's Method for Determining Qibla Direction Using Raspberry Pi," *Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control*, February 28, 2022, https://doi.org/10.22219/kinetik.v7i1.1342.

[4] Rusdin Muhalling et al., "The Qibla Directional Accuracy Determination Analysis Using Spherical Trigonometric Method and Google Earth," *NeuroQuantology* 20, no. 5 (April 30, 2022): 107–14, https://doi.org/10.14704/nq.2022.20.5.NQ22153.

[5] ABD. Karim Faiz, "Kalibrasi Arah Kiblat Masjid Agung Parepare Prespektif Fiqih Dan Ilmu Falak," *Iqtisad: Reconstruction of Justice and Welfare for Indonesia* 9, no. 2 (December 31, 2022): 231, https://doi.org/10.31942/iq.v9i2.6611.

[6] Akhmad - Husein, Ahmad - Izzuddin, and Muhammad Said Fadhel, "The Effect Of Magnetic Declination Correction On Smartphones Compass Sensors In Determining Qibla Direction," *Al-Hilal: Journal of Islamic Astronomy* 3, no. 2 (October 31, 2021): 43–74, https://doi.org/10.21580/al-hilal.2021.3.2.8309.

[7] Shofwatul Aini, "Uji Akurasi Rasd Al-Qiblat Global Sebagai Metode Penentuan Arah Kiblat," *Al-Ahkam Jurnal Ilmu Syari'ah Dan Hukum* 7, no. 1 (June 30, 2022): 57–71, https://doi.org/10.22515/alahkam.v7i1.5412.

[8] 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 (July 24, 2023): 1–28, https://doi.org/10.21580/al-hilal.2023.5.1.13734.

[9] Nurulhuda Ahmad Zaki et al., "Cerapan Istiwa' Matahari Dalam Penentuan Arah Kiblat Di Malaysia," *Sains Humanika* 11, no. 2 (April 30, 2019), https://doi.org/10.11113/sh.v11n2.1452.

[10] Anisah Budiwati, "Tongkat Istiwa', Global Positioning System (Gps) Dan Google Earth Untuk Menentukan Titik Koordinat Bumi Dan Aplikasinya Dalam Penentuan Arah Kiblat," *Al-Ahkam* 26, no. 1 (April 14, 2016): 65, https://doi.org/10.21580/ahkam.2016.26.1.808.

certain times of the day, as well as dependence on clear weather.[11] In the modern context, traditional methods like this are starting to be abandoned along with the emergence of more practical digital alternatives.[12]

Digital technologies, especially those based on Metaverse, are opening new avenues for Qibla direction determination with claimed higher accuracy.[13] Metaverse, as a virtual representation of the real world,[14] allows the integration of various astronomical and geographical data elements in one platform. Through the use of applications or devices connected to this technology, Muslims can determine the Qibla direction quickly and accurately without having to rely on direct observation of the sun's position.[15] In addition, this technology enables Qibla direction determination in various environmental conditions, including in enclosed spaces or areas with physical obstructions, which is one of the major challenges for traditional methods.[16]

However, while digital technology offers a number of advantages, questions arise regarding the validity and legitimacy of its use in the perspective of Islamic law (fiqh).[17] The fiqh tradition developed in various Islamic schools of thought has emphasized the importance of direct human involvement in determining the Qibla direction, either through observation or the use of simple tools such as a compass or an istiwa stick.[18] As such, there is a concern that complete reliance on digital technology may override long-held fiqh principles. In addition, the relatively new Metaverse technology still requires further study in the context of the integrity of the astronomical data used,[19] as well as the

[11] Novi Arisafitri, "Convergence Of Qibla Direction Accuracy Of The Old Air Tiris Grand Mosque Kampa Riau," *Al-Hilal: Journal of Islamic Astronomy* 4, no. 2 (October 31, 2022): 203–24, https://doi.org/10.21580/al-hilal.2022.4.2.14324.

[12] W. S. Mada Sanjaya et al., "Determining Qibla Direction Using Al-Biruni's First Method from Kitab Tahdid Nihayat Al-Amakin with The Implementation Based on Board Arduino MCU, GPS Module, and Digital Compass," in *2019 International Seminar on Application for Technology of Information and Communication (ISemantic)* (IEEE, 2019), 513–18, https://doi.org/10.1109/ISEMANTIC.2019.8884330.

[13] Muhalling et al., "The Qibla Directional Accuracy Determination Analysis Using Spherical Trigonometric Method and Google Earth."

[14] Mursyid Fikri et al., "The Potential Utilization of Metaverse as a Praying Space from the Perspective of Maslahah Mursalah," *Journal of Ecohumanism* 3, no. 4 (August 16, 2024): 2143–60, https://doi.org/10.62754/joe.v3i4.3713.

[15] Azmi Awang Md. Isa et al., "Mobile Prayer Times and Qiblat Direction Using GPS," in *2007 Asia-Pacific Conference on Applied Electromagnetics* (IEEE, 2007), 1–5, https://doi.org/10.1109/APACE.2007.4603863.

[16] Muttaqin, "The Utilization Of Augmented Reality Technology In Determining Qibla Direction (Analysis Of Miqat Applications By Samer Joudi)."

[17] Sri Wahyuni, Samsuddin Samsuddin, and Ekawati Hamzah, "Qibla Direction Accuracy Analysis Based On Astronomy (Google Earth), Perspective Of Islamic Law," *Journal of Islam and Science* 9, no. 1 (July 13, 2022): 39–45, https://doi.org/10.24252/jis.v9i1.30111.

[18] Anisah Budiwati, "Fiqh Hisab Arah Kiblat: Kajian Pemikiran Dr. Ing Khafid Dalam Software Mawāqit," *Unisia* 36, no. 81 (2014): 97–111, https://doi.org/10.20885/unisia.vol36.iss81.art1.

[19] Mursyid Fikri and St Rajiah, "The Challenges And Opportunities Of Islamic Education In The Era Of Metavers . (Method and Implementation of Astronomy Learning)," 2022, 35–45.

potential distortion of information that may occur in the process of integrating the data into a digital platform.

In this research, a comparative study was conducted to evaluate the level of accuracy of the two methods of determining the Qibla direction of the istiwa stick, in this case istiwaaini[20] as a representation of the traditional method, and Metaverse qibla finder as a representation of the digital method.[21] By involving three mosques in South Sulawesi as research locations, it is hoped that a clearer picture of the differences in the results produced by the two methods can be obtained. Data collection is done through field observation for the istiwa stick method, as well as the use of Metaverse-based applications that are connected to the latest astronomical data. The results of this research will not only compare the accuracy of the two methods, but will also provide insight into the potential for technological development in helping Muslims perform their worship better.

This research also seeks to examine how the use of technology in Qibla direction determination can be integrated with existing fiqh guidelines. This is important given that rapid technological developments are often not accompanied by adequate legal adaptations, leading to confusion among Muslims.[22] Through collaboration between fiqh experts, astronomical scientists, and technology developers, it is hoped that a new standard in Qibla direction determination can be created that does not only rely on technological accuracy, but also considers aspects of sharia that have been the main guidelines in worship.[23]

Thus, this research is expected to make a significant contribution to the development of knowledge in the field of Qibla direction determination, especially in the context of integration between traditional and digital methods. In addition, this research can also open a wider discussion on the role of technology in religious practice and how Muslims can adopt technology without abandoning basic principles in religion.[24] Finally, it is hoped that the results of this research can provide a more effective and efficient solution for Muslims in determining the Qibla direction, especially in complex situations and conditions.

TECHNIQUES AND ALGORITHMS FOR QIBLA DIRECTION MEASUREMENT USING GPS

[20] Misrahul Safitri, "Studi Komparasi Terhadap Akurasi Istiwaaini Dengan Kompas Kiblat Android 'Muslim Go' Dalam Pengukuran Arah Kiblat," *AL - AFAQ : Jurnal Ilmu Falak Dan Astronomi* 4, no. 1 (June 30, 2022): 78–94, https://doi.org/10.20414/afaq.v4i1.5070.

[21] Sang Min Park and Young Gab Kim, "A Metaverse: Taxonomy, Components, Applications, and Open Challenges," *IEEE Access* 10 (2022): 4209–51, https://doi.org/10.1109/ACCESS.2021.3140175.

[22] Ahmad Izzuddin, "The Problems of the Relationship between Science and Religion in Qibla Direction Calibration at the Great Mosque of Demak and Baiturrahman Mosque in Semarang, Indonesia," *JIL: Journal of Islamic Law* 3, no. 2 (August 1, 2022): 111–31, https://doi.org/10.24260/jil.v3i2.823.

[23] Fajar Fathurahman, "Learning Innovation of Qibla Direction with Mobile-Based App by Adapting Computational Thinking," *Jurnal Iqra' : Kajian Ilmu Pendidikan* 6, no. 1 (June 2, 2021): 211–24, https://doi.org/10.25217/ji.v6i1.981.

[24] Mursyid Fikri. indriana, "Persepsi Dan Harapan Netizen Mengenai Variabilitas Waktu Perayaan Idul Fitri Di Indonesia," *Al Qalam: Jurnal Ilmiah Keagamaan Dan Kemasyarakatan* 18, no. 4 (2024): 2791–2803, https://doi.org/http://dx.doi.org/10.35931/aq.v18i4.3450.

Qibla direction measurement using GPS is one of the modern methods that utilizes the global positioning system to determine the direction of the Kaaba with high precision.[25] This technique works based on the latitude and longitude coordinates of the user and the geographical coordinates of the Kaaba (21.4225° N, 39.8262° E). The algorithm used in this measurement utilizes the geodetic formula to calculate the azimuthal angle,[26] which is the angle measured clockwise from north to Qibla.[27] This method overcomes the limitations of traditional tools such as compasses, which can be affected by the earth's magnetic field and do not always give accurate results, especially in areas with magnetic disturbances.

The basic algorithm used to determine the Qibla direction with GPS is the Haversine or Vincenty formula, which is used to calculate the distance and angle between two points on the Earth's surface based on latitude and longitude coordinates.[28] Haversine calculates the azimuthal angle by combining the latitude and longitude differences of the user's position with the position of the Kaaba.[29] This angle is then converted into the exact Qibla direction with reference to north. This algorithm is effective for measuring distance and direction with high precision, as it takes into account the non-spherical shape of the earth (geoid), which allows for more accurate results compared to methods that only use a two-dimensional map approach.

One of the main advantages of using GPS in Qibla direction measurement is its ability to work in almost all geographical conditions,[30] including in areas that are difficult to access or in urban areas with tall buildings that can block the direct view of the sun. GPS technology relies on satellite signals that can be accessed globally, so users do not need additional tools such as a yardstick or compass.[31] In addition, GPS-based applications often

[25] Yahya Tawil, "A Hardware Implementation Of An Open-Source Qibla Direction Finder With Tilt Compensation Using 9-DOF IMU And GPS," in *2023 Innovations in Intelligent Systems and Applications Conference (ASYU)* (IEEE, 2023), 1–6, https://doi.org/10.1109/ASYU58738.2023.10296590.

[26] Auzi'ni Syukron Kamal Ahmad and Muslich Shabir, "Application Of Effective Azimuth Different Formula In Determining The Qibla Direction," *Al-Hilal: Journal of Islamic Astronomy* 4, no. 2 (March 21, 2023): 115–32, https://doi.org/10.21580/al-hilal.2022.4.2.12069.

[27] ANDI SUSANTO, Diana Nurfadilah, and Siti Zaenab, "Reaktualisasi Pengukuran Arah Kiblat Dengan Metode Segitiga Bola Pada Masjid Dan Musholla," *KASBANA : Jurnal Hukum Ekonomi Syariah* 1, no. 2 (July 31, 2021): 85–100, https://doi.org/10.53948/kasbana.v1i2.25.

[28] Hagar Mahmoud and Nadine Akkari, "Shortest Path Calculation: A Comparative Study for Location-Based Recommender System," in *2016 World Symposium on Computer Applications & Research (WSCAR)* (IEEE, 2016), 1–5, https://doi.org/10.1109/WSCAR.2016.16.

[29] Binti Maftukhah et al., "The Analysis and Implementation of Haversine Formulas in Determining Qibla Direction by Using Sphiral Trigonometry in Indonesia," in *Proceedings of the Built Environment, Science and Technology International Conference* (SCITEPRESS - Science and Technology Publications, 2018), 268–71, https://doi.org/10.5220/0008906202680271.

[30] Tawil, "A Hardware Implementation Of An Open-Source Qibla Direction Finder With Tilt Compensation Using 9-DOF IMU And GPS."

[31] Sanjaya et al., "Determining Qibla Direction Using Al-Biruni's First Method from Kitab Tahdid Nihayat Al-Amakin with The Implementation Based on Board Arduino MCU, GPS Module, and Digital Compass."

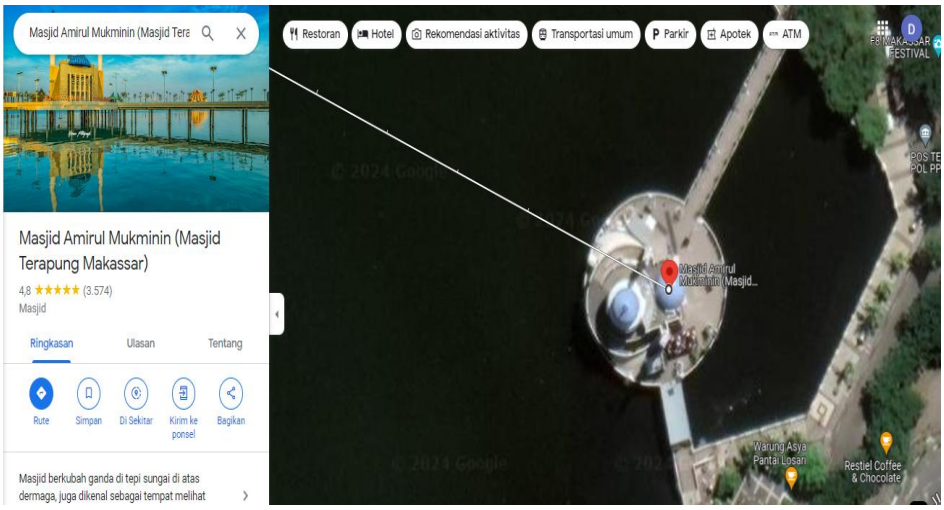
come with an easy-to-use user interface, where users only need to input their location, and the application automatically calculates the Qibla direction. This makes the GPS method a practical solution for Muslims in the digital age.

However, while GPS offers convenience and precision, there are some challenges faced in its use. GPS signals can be disrupted by external factors such as bad weather, tall buildings or bumpy terrain, which can affect the accuracy of the measurement results.[32] In addition, the algorithms used to calculate Qibla direction must account for local deviations in true north and magnetic north,[33] which can add complexity to the calculation. Some applications may also experience small deviations if they are not regularly updated to adjust for changes in global geodetic parameters. Therefore, it is important for Qibla-based GPS applications to be continuously updated and verified for accuracy.[34]

Overall, GPS-based Qibla direction measurement techniques and algorithms have made significant progress in helping Muslims determine the Qibla direction more quickly and accurately. The integration between GPS and digital technology, as seen in the use of the Metaverse application, allows for more intuitive measurements with real-time and relevant data. However, further testing and validation in the context of widespread use is needed to ensure that the accuracy of these algorithms remains consistent under various geographical and technical conditions. The combination of these modern techniques with traditional principles of Qibla direction determination may result in a more comprehensive and reliable approach in the future.

Implementation of haversine formula on Augmented Reality and Maps on metaverse as follows:

1) Amirul Mukminin Mosque (Makassar Floating Mosque)



[32] Nur Hazliza Ariffin and Norhana Arsad, "MEMS Gyro and Accelerometer as North-Finding System for Bulk Direction Marking," *IEEE Access* 10 (2022): 114214–22, https://doi.org/10.1109/ACCESS.2022.3217494.

[33] E. L. Afraimovich, V. V. Demyanov, and T. N. Kondakova, "Degradation of GPS Performance in Geomagnetically Disturbed Conditions," *GPS Solutions* 7, no. 2 (August 1, 2003): 109–19, https://doi.org/10.1007/s10291-003-0053-7.

[34] Octavian Thor Pleter and Cristian Emil Constantinescu, "Study on the Transition to True North in Air Navigation," *Aerospace* 10, no. 11 (October 25, 2023): 912, https://doi.org/10.3390/aerospace10110912.

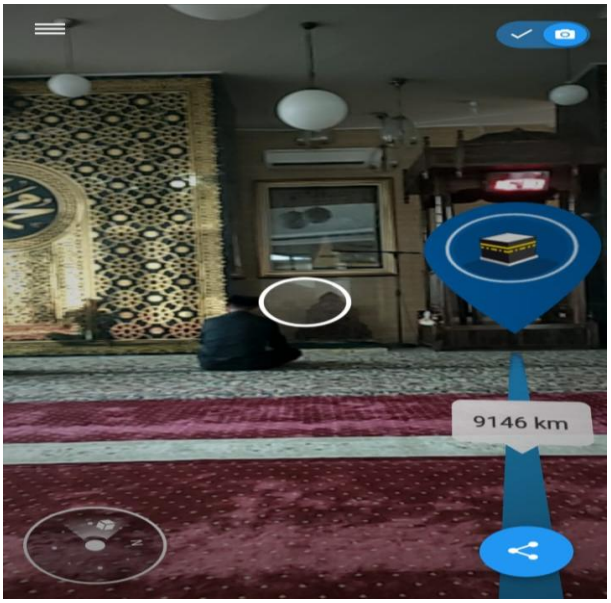


Figure 1 : Qibla Direction of Amirul Mukminin Mosque

Distance measurement algorithm of Qibla direction of Amirul Mukminin Mosque using phyton program:

```
from math import *
def haversine(lon1, lat1, lon2, lat2):
    """
    Calculate the great circle distance between two points
    on the earth (specified in decimal degrees)
    """
    # convert decimal degrees to radians
    lon1, lat1, lon2, lat2 = map(radians, [lon1, lat1, lon2, lat2])

    # haversine formula
    dlon = lon2 - lon1
    dlat = lat2 - lat1
    a = sin(dlat/2)**2 + cos(lat1) * cos(lat2) * sin(dlon/2)**2
    c = 2 * asin(sqrt(a))
    r = 6371 # Radius of earth in kilometers. Use 3956 for miles
    return c * r

center_point = [{'lat': 21.42252816637070, 'lng': 39.826190723236785}]
test_point = [{'lat': -5.14685454199396, 'lng': 119.40803952564703}]
```

```
lat1 = center_point[0]['lat']
lon1 = center_point[0]['lng']
lat2 = test_point[0]['lat']
lon2 = test_point[0]['lng']
a = haversine(lon1, lat1, lon2, lat2)

print('Distance (km) : ', a)
Distance (km) :  9145.510156215627
```

So based on the results of the calculation of the distance of the Amirul Mukminin mosque to the Qibla using the Haversine formula based on the Python program is 9145.510156215627 KM

2) Mosque Raya makassar

Figure 2: Qibla Direction of Makassar Grand Mosque

Distance measurement algorithm of Qibla direction of Makassar Grand Mosque using phyton program:

```
from math import *
def haversine(lon1, lat1, lon2, lat2):
    """
    Calculate the great circle distance between two points
    on the earth (specified in decimal degrees)
    """
    # convert decimal degrees to radians
    lon1, lat1, lon2, lat2 = map(radians, [lon1, lat1, lon2, lat2])

    # haversine formula
    dlon = lon2 - lon1
    dlat = lat2 - lat1
    a = sin(dlat/2)**2 + cos(lat1) * cos(lat2) * sin(dlon/2)**2
    c = 2 * asin(sqrt(a))
    r = 6371 # Radius of earth in kilometers. Use 3956 for miles
    return c * r

center_point = [{'lat': 21.422528166370707, 'lng': 39.826190723236785}]
test_point = [{'lat': -5.130656488559506, 'lng': 119.4199918033474}]
lat1 = center_point[0]['lat']
lon1 = center_point[0]['lng']
lat2 = test_point[0]['lat']
lon2 = test_point[0]['lng']
a = haversine(lon1, lat1, lon2, lat2)
print('Distance (km) : ', a)
Distance (km) :  9146.044635685364
```

So based on the results of the calculation of the distance of the Makassar Raya mosque to the Qibla using the Haversine formula based on the Phyton program is 9146. 044635685364 KM.

3) Jami Al Ittihad Mosque

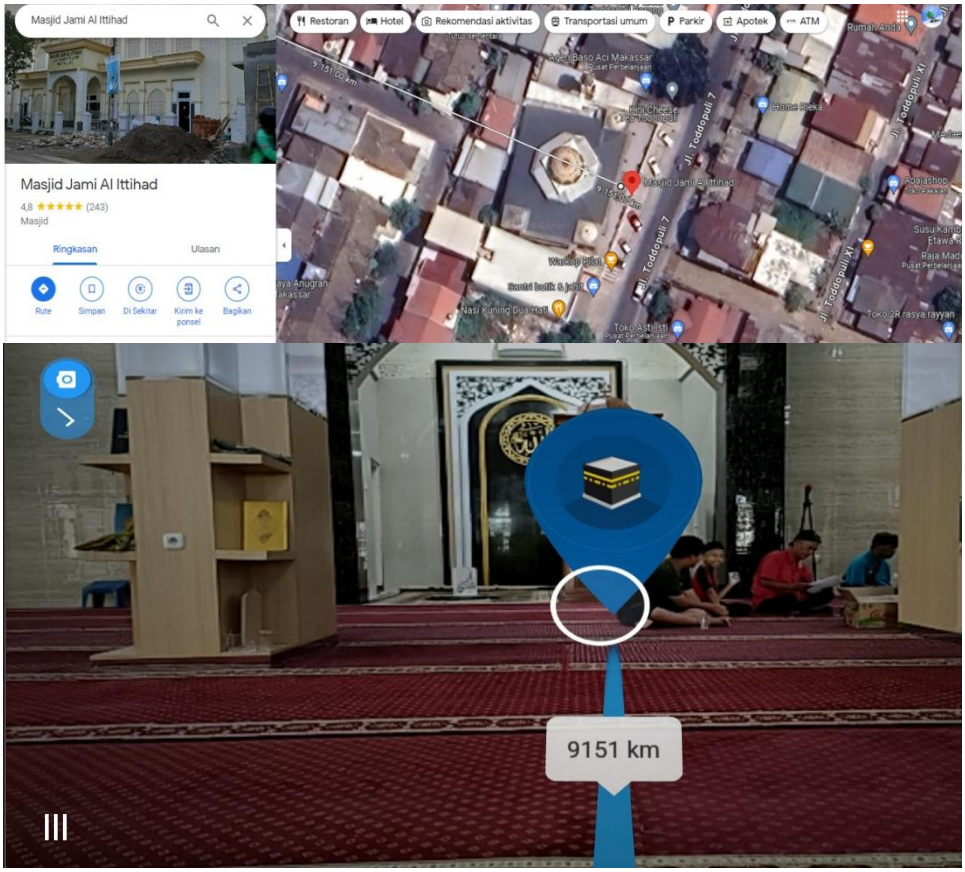


Figure 3: Qibla Direction of Jami Al Ittihad Mosque

Distance measurement algorithm of Qibla direction of Jami Al Ittihad Mosque using phyton program:

```
from math import *
def haversine(lon1, lat1, lon2, lat2):
    """
    Calculate the great circle distance between two points
    on the earth (specified in decimal degrees)
    """
    # convert decimal degrees to radians
    lon1, lat1, lon2, lat2 = map(radians, [lon1, lat1, lon2, lat2])
    # haversine formula
    dlon = lon2 - lon1
    dlat = lat2 - lat1
    a = sin(dlat/2)**2 + cos(lat1) * cos(lat2) * sin(dlon/2)**2
    c = 2 * asin(sqrt(a))
    r = 6371 # Radius of earth in kilometers. Use 3956 for miles
    return c * r
```

```
center_point = [{'lat': 21.422528166370707, 'lng': 39.826190723236785}]
test_point = [{'lat': -5.1655962872523045, 'lng': 119.45441235816273}]

lat1 = center_point[0]['lat']
lon1 = center_point[0]['lng']
lat2 = test_point[0]['lat']
lon2 = test_point[0]['lng']
a = haversine(lon1, lat1, lon2, lat2)
print('Distance (km) : ', a)
Distance (km) :  9151.052314705317
```

So based on the results of the calculation of the distance between the Jami Al Ittihad Makassar mosque and the Qibla using the Haversine formula based on the Python program is 9151.052314705317 KM.

ACCURACY OF QIBLA DIRECTION MEASUREMENT USING METAVERSE AND ISTIWAAINI

After taking measurements with the metaverse application of the Qibla direction displayed by the image, the accuracy of the direction was tested using the istiwaaini instrument, which refers to the following concept. First, the istiwaaini instrument is used to determine a reference point that corresponds to the position of the Qibla direction of the mosque and the sun. Thus, this instrument can help determine the correct direction based on the position of the celestial body in relation to the observation point on the earth's surface.[35] Secondly, through the comparison between the measurement results using the augmented reality application and the measurement results of directional accuracy with the istiwaaini instrument, the level of accuracy of the direction shown by the application in determining the Qibla direction can be evaluated.

Directional accuracy testing using the istiwaaini instrument is a critical step in evaluating the accuracy and reliability of Qibla direction measurements provided by the metaverse application. By utilizing the basic concept of the istiwaaini instrument, which relies on the vertical position of a solar object in relation to an observation point on the earth's surface, an objective comparison can be made between the measurement results of the two methods. This makes it possible to identify and correct potential errors or inaccuracies that may occur in the measurement of Qibla direction using augmented reality applications. Thus, the use of istiwaaini instruments in direction accuracy tests is important to ensure the reliability and accuracy of Qibla direction measurement results provided by augmented reality technology.

1) Amirul Mukminin Mosque (Makassar Floating Mosque)

[35] Muhammad Faishol Amin, "Global Rasdhul Qibla: The Probability of Four Times in A Year Study," *JURNAL PENELITIAN*, November 20, 2018, 175, https://doi.org/10.28918/jupe.v15i2.1651.

Analysis of the measurement of the Qibla direction of the Amirul Mukminin mosque using Istiwaaini:

Geographical Location:

Latitude :- 5°08'48" LS

Longitude : 119°24'28" BT

Calculating the Qibla Azimut of Amirul Mukminin Mosque (Floating Mosque, Makassar):

a) Required Data

Longitude of Place (λ^x) = 119°24'28" BT

Longitude of Kaaba (λ^k) = 39° 49' 34" BT

Latitude of Place (φ^x) = -05°08'48" LS

Latitude of the Kaaba (φ^k) = 21°25' 21" LU

Longitude Difference (C) = (λ^x) - (λ^k)

= 119°24'28" BT - 39° 49' 34" BT

= 79°34'54" (West)

b) The Process of Determining Qibla Direction :

Cotan Qibla Direction (AK) :

= tan (φ^k) x cos (φ^x) ÷ sin C – Sin (φ^x) ÷ tan C

Cotan AK = tan 21°25' 21" x cos -5°08'48"÷ sin 79°34'54" – sin -5°08'48" ÷ tan 79°34'54"

Ak = $\tan^{-1}$(tan 21°25' 21" x cos -5°08'48"÷ sin 79°34'54" – sin -5°08'48" ÷ tan 79°34'54")$^{-1}$

Ak = 67°31'10,88" (Utara ke Barat)

c) Calculating Qibla Azimuth (Az)

Az = 360° - 67°31'10,88"

Az = 292°28'49" UTSB

d) Calculating the Sun's Direction when measuring on April 25, 2024 at 11:45 am e: 0°01'51,69" d; 13°00'31"

Cot AM = tan (d) x cos (φ^x) ÷ sin t – Sin (φ^x) ÷ tan t

Where the formula for finding t is as follows:

t = (LMT + e – (BD-BT)÷ 15)-12)x15

t = (11:45 + 0°01'51,69"-(120°-119°24'28") ÷ 15)-12) X 15

t = -3°52'16,65"

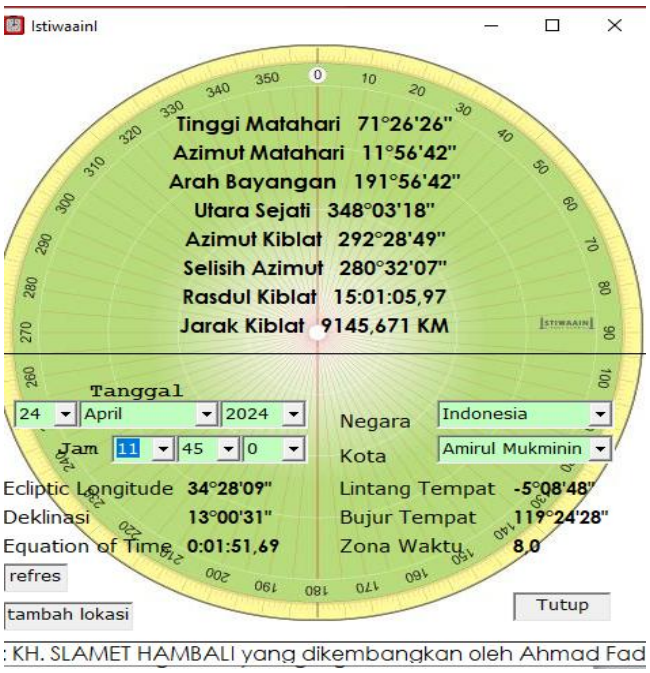
t value is inputted in the Sun Direction formula.

Cot AM = tan (d) x cos (φ^x) ÷ sin t – Sin (φ^x) ÷ tan t

AM = $\tan^{-1}$(tan 13°20'05" x cos -05°08'48" ÷ sin -3°49'57,5" – Sin – 05°08'48" ÷ tan -3°49'57,5")$^{-1}$

AM = 11°56'42" UT

Istiwaaini Application Input



So based on the results of the calculation and measurement of the Qibla direction, the difference in azimuth between the Qibla and the Amirul Mukminin mosque on April 24, 2024 at 11:45 am is: 280°32'07" UTSB.

2) Mosque Raya makassar

Analysis of the measurement of the Qibla direction of the Makassar Grand Mosque using Istiwaaini:

Geographical Location:

Latitude :-05°07'50"LS

Longitude : 119°25'11" BT

Calculating the Qibla Azimut of the Makassar Grand Mosque:

a) Required Data

Longitude of Place (λ^x) = 119°25'11"BT

Longitude of Kaaba (λ^k) = 39° 49' 34" BT

Latitude of Place (φ^x) = -05°07'50" LS

Latitude of the Kaaba (φ^k) = 21°25' 21" LU

Longitude Difference (C) = (λ^x) - (λ^k)

= 119°25'11"BT - 39° 49' 34" BT

= 79°35'37" (West)

b) The Process of Determining Qibla Direction :

Cotan Qibla Direction (AK) :

= tan (φ^k) x cos (φ^x) ÷ sin C – Sin (φ^x) ÷ tan C

Cotan AK = tan 21°25' 21" x cos -05°7'50"÷ sin 79°35'37" – sin -05°7'50"

÷ tan 79°35'37"

Ak = $\tan^{-1}$(tan 21°25' 21" x cos -05°7'50"÷ sin 79°35'37" – sin -05°7'50" ÷ tan 79°35'37")$^{-1}$

Ak = 67°31'24" (North to West)

c) Calculating Qibla Azimuth (Az)

Az = 360° - 67°31'24"

Az = 292°28'36" UTSB

d) Calculating the Sun's Direction during measurement on April 28, 2024 at 09:45 am e: 0°02'29,35" d; 14°15'52"

Cot AM = tan (d) x cos (φ^x) ÷ sin t – Sin (φ^x) ÷ tan t

Where the formula for finding t is as follows:

t = (LMT + e – (BD-BT)÷ 15)-12)x15

t = (09:45 + 0°02'29,35" -(120°-119°25'11") ÷ 15)-12) X 15

t = -33°42'29"

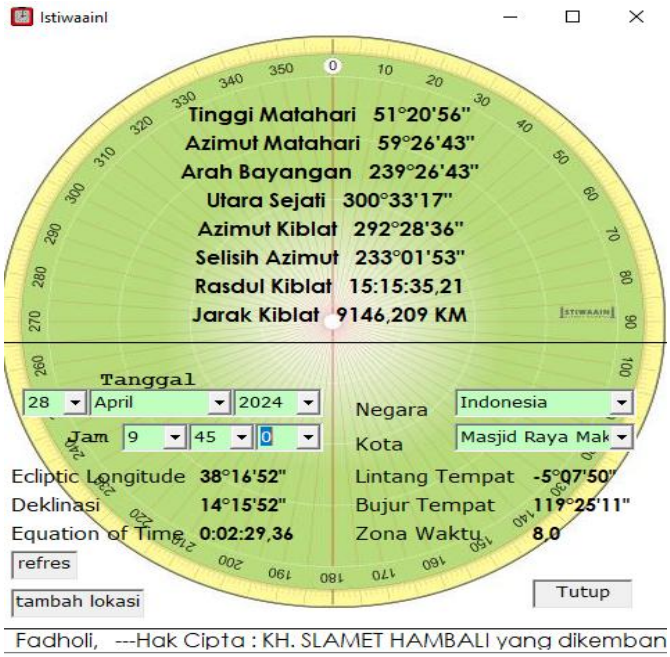
t value is inputted in the Sun Direction formula by ignoring the Negative sign.

Cot AM = tan (d) x cos (φ^x) ÷ sin t – Sin (φ^x) ÷ tan t

AM = $\tan^{-1}$(tan 14°15'52" x cos -05°07'50" ÷ sin 33°42'29" – Sin – -05°07'50" ÷ tan 33°42'29")$^{-1}$

AM = 59°26'43" UT

Istiwaaini Application Input



So based on the results of the calculation and measurement of the Qibla direction, the difference in azimuth between the Qibla and the mosque on April 28, 2024 at 9:45 am is: 233°01'53" UTSB..

3) Jami Al Ittihad Mosque

Analysis of the Qibla direction measurement of the Jami Al-Ittihadi mosque using Istiwaaini:

Geographical Location:

Latitude : -05°09'56" LS

Longitude : 119°27'15" BT

Calculating the Qibla Azimut of Jami Al-Ittihadi Mosque Makassar:

a) Required Data

Longitude of Place (λ^x) = 119°27'15" BT

Longitude of Kaaba (λ^k) = 39° 49' 34" BT

Latitude of Place (φ^x) = -05°09'56" LS

Latitude of the Kaaba (φ^k) = 21°25' 21" LU

Longitude Difference (C) = (λ^x) - (λ^k)

= 119°27'15" BT - 39° 49' 34" BT

= 79°37'41" (West)

b) The Process of Determining Qibla Direction :

Cotan Qibla Direction (AK) :

= tan (φ^k) x cos (φ^x) ÷ sin C – Sin (φ^x) ÷ tan C

Cotan AK = tan 21°25' 21" x cos -05°09'56" ÷ sin 79°37'41" – sin -05°09'56" ÷ tan 79°37'41"

Ak = $\tan^{-1}$(tan 21°25' 21" x cos -05°09'56" ÷ sin 79°37'41" – sin -05°09'56" ÷ tan 79°37'41")$^{-1}$

Ak = 67°31'26" (North to West)

c) Calculating Qibla Azimuth (Az)

Az = 360° - 67°31'26""

Az = 292°28'34" UTSB

d) Calculating the Sun's Direction during measurement on April 29, 2024 at 08:53 am e: 0°02'37,44" d; 14°33'53"

Cot AM = tan (d) x cos (φ^x) ÷ sin t – Sin (φ^x) ÷ tan t

Where the formula for finding t is as follows:

t = (LMT + e – (BD-BT)÷ 15)-12)x15

t = (08:53 + 0°02'37,44" -(120°-119°27'15") ÷ 15)-12) X 15

t = -46°38'23,4"

t value is inputted in the Sun Direction formula by ignoring the Negative sign.

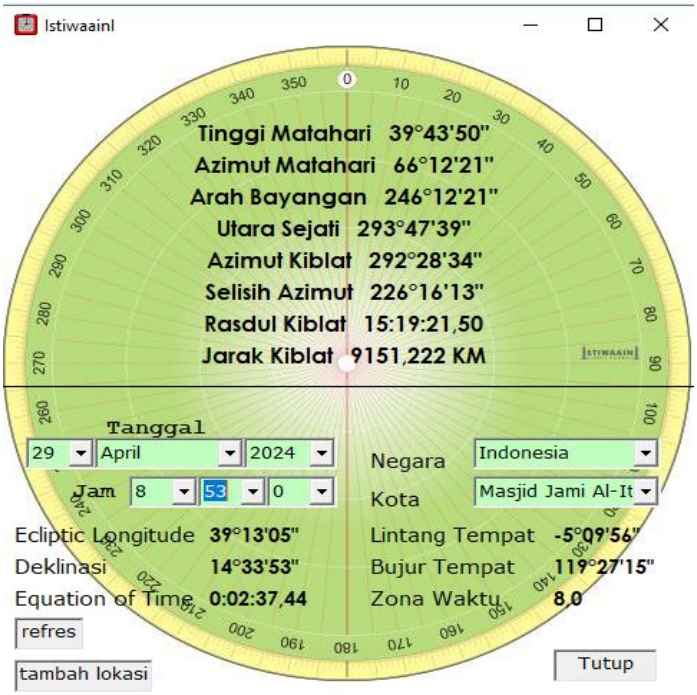
Cot AM = tan (d) x cos (φ^x) ÷ sin t – Sin (φ^x) ÷ tan t

AM = $\tan^{-1}$(tan 14°33'53" x cos -05°09'56" ÷ sin 46°38'23,4"– Sin –

$-05°09'56'' \div \tan 46°38'23,4'')^{-1}$

AM = 66°12'21'' UT

Istiwaaini Application Input



So based on the results of the calculation and measurement of the Qibla direction, the difference in azimuth between the Qibla and the Al-Ittihadi jami mosque on April 29, 2024 at 8:53 am is: 226°16'13" UTSB

POTENTIAL AND OBSTACLES OF METAVERSE TECHNOLOGY UTILIZATION IN QIBLA DIRECTION.

Looking at the results of the measurement trials of the Qibla direction of ten mosques that have been tested for accuracy using the following metaverse data differences and measurement accuracy using the Istiwaaini instrument:

NO	Mosque Name	Geographical Location	Qibla Azimuth	Metaverse Direction	Istiwaaini Direction
1	Amirul Mukminin (Makassar Floating Mosque)	5°08'48''S 119°24'28''E	292°28'49'' UTSB	63°15' (North to West)	67°31'(North to West)
2	Great Mosque of Makassar	05°07'50''S 119°25'11''E	292°28'36'' UTSB	67°31' (North to West)	67°31'(North to West)

3	Jami Al Ittihad Mosque	05°09'56" S 119°27'15"E	292°28'34" UTSB	63°31' (North to West)	67°31'(North to West)

From the table above, the three mosques that researchers tested the accuracy of their Qibla direction found that one mosque, namely the Amirul Mukminin Mosque, showed a significant difference in Qibla direction when the results of the Istiwaaini method were compared with the results of the metaverse.

Qibla direction determination using metaverse technology requires special attention to network quality and the geographical conditions of the measurement location. Good network quality is crucial in ensuring the accuracy of data received and processed by devices connected to metaverse. A stable and fast network will reduce latency and improve the accuracy of location information used to determine Qibla direction. [36] Conversely, poor network quality can cause delays or errors in data transmission, which in turn can affect the accuracy of the displayed Qibla direction.[37]

In addition to network quality, the geographical conditions surrounding the measurement location also play an important role in the accuracy of qibla direction using metaverse. Physical environments such as tall buildings, hilly terrain, or other natural obstructions can interfere with GPS signals and affect the accuracy of location data.[38] For example, measurements taken in areas with many physical obstructions may require additional corrections or the use of more complex algorithms to ensure accurate location data.[39] Therefore, an in-depth understanding of the surrounding geographical conditions and topography is essential in the context of using metaverse for Qibla direction determination.

Reliance on satellite technology and digital maps in the metaverse also requires careful verification and calibration. These technologies, while sophisticated, still rely on reference data that can have a certain margin of error.[40] For example, the digital maps used may not always be completely accurate or up-to-date, which can lead to small but

[36] Sachin Sabloak et al., "Analisis Pemantauan Lan Menggunakan Metode Qos Dan Pengklasifikasian Status Jaringan Internet Menggunakan Algoritma Naive BAYES," *Jurnal Ilmiah Teknologi Infomasi Terapan* 4, no. 2 (April 30, 2018), https://doi.org/10.33197/jitter.vol4.iss2.2018.159.

[37] Churun Lu'lu'il Maknun, "Aplikasi Spherical Trigonometry Dalam Menentukan Arah Kiblat Umat Islam," *Jurnal Fourier* 10, no. 2 (October 31, 2021): 57–66, https://doi.org/10.14421/fourier.2021.102.57-66.

[38] Lathif Hanafir Rifqi and Ana Zahrotun Nihayah, "Faktor Penentu Sikap Penggunaan Platform Pembayaran Digital Bagi Pelaku Usaha Mikro Kecil Kreatif," *Jurnal SEKURITAS (Saham, Ekonomi, Keuangan Dan Investasi)* 6, no. 1 (September 1, 2022): 17, https://doi.org/10.32493/skt.v6i1.22420.

[39] Petti Indrayati Sijabat et al., "Algoritma Backpropagation Prediksi Harga Komoditi Terhadap Karakteristik Konsumen Produk Kopi Lokal Nasional," *Digital Zone: Jurnal Teknologi Informasi Dan Komunikasi* 11, no. 1 (May 8, 2020): 96–107, https://doi.org/10.31849/digitalzone.v11i1.3880.

[40] Yogi Purna Rahardjo, Basrum Basrum, and Taufik Djatna, "Analysis and Design of the Digital Rice Certification System as a Seed Breeder Marketplace and Varieties Adopt Improvement," *Industria: Jurnal Teknologi Dan Manajemen Agroindustri* 7, no. 3 (December 28, 2018): 143–52, https://doi.org/10.21776/ub.industria.2018.007.03.2.

significant differences in Qibla direction determination. The use of accurate satellite data and regular updates of digital maps are essential to minimize these errors and ensure that the Qibla direction displayed corresponds to the actual direction of the qibla. [41]

Considering these factors, it can be concluded that establishing the Qibla direction using metaverse requires a holistic and integrated approach. A combination of optimal network quality in-depth understanding of geographical conditions, and regular data verification and calibration are key to achieving the expected accuracy. Therefore, the use of metaverse technology in this context must be supported by a robust technological infrastructure and close supervision to ensure accurate and reliable results.

It is important to consider that in providing legal certainty and confidence in worship, metaverse technology can be a useful second alternative in determining Qibla direction when in public locations. Metaverse, which utilizes virtual and augmented reality technology, can provide intuitive and easily accessible visualizations of Qibla direction through devices that support this technology. [42] Thus, individuals who are in public locations or other than mosques can obtain quick and practical guidance, which is helpful in maintaining consistency of worship practices.

However, to provide legal certainty in the use of metaverse as a tool for determining the Qibla direction, an in-depth study is needed from a sharia perspective.[43] This includes validating the reliability and accuracy of the technology in the context of determining the Qibla direction. According to several scientific studies, the accuracy and precision of metaverse-based technology is highly dependent on the quality of the geospatial data used as well as the environmental conditions at the time of measurement. Therefore, ensuring that metaverse devices and applications use valid and regularly updated data is essential to maintain the legal validity of the Qibla direction determined.

In addition, the integration of metaverse as a tool in determining Qibla direction must also consider the education and socialization factor to the people. Many users may not be familiar with this technology or doubt its reliability compared to traditional methods such as compasses or GPS-based applications. Therefore, adequate counseling and training on the use and advantages of metaverse in the context of Qibla direction determination can increase the acceptance and confidence of the Ummah in this technology. With the right approach, the metaverse can be seen as a legitimate and useful complement in the daily practice of worship.

Finally, from a practical and technological perspective, the metaverse should continue to be developed taking into account input from scholars and technologists. The development

[41] Siti Mawar Rini Wintang et al., "Pengukuran Tingkat Kapabilitas Sistem Pengolahan Data Survei Pada Manajamen Kinerja Dan Manajemen Data Operasi Menggunakan Dmbok Dan Cobit2019 Di BPS RI," *Jurnal Teknologi Informasi Dan Ilmu Komputer* 10, no. 3 (July 1, 2023): 573, https://doi.org/10.25126/jtiik.20231036533.

[42] Willy Permana Putra et al., "Aplikasi 3D Virtual Reality Menggunakan Unity Berbasis Mobile Sebagai Media Pengenalan Lingkungan Di SMK Negeri 1 Indramayu," *Jurnal MIPA* 8, no. 3 (October 14, 2019): 99, https://doi.org/10.35799/jmuo.8.3.2019.25584.

[43] Maknun, "Aplikasi Spherical Trigonometry Dalam Menentukan Arah Kiblat Umat Islam."

of clear operational standards and procedures as well as periodic accuracy of metaverse applications used for qibla direction determination will ensure that this technology meets both sharia and technical criteria. Thus, metaverse can serve as a trusted additional solution in helping Muslims around the world to perform worship with confidence and peace of mind, especially when in public places or locations far away from Mosques

CONCLUSION

A comparison between the traditional method of determining Qibla direction using the istiwa stick and digital technology through metaverse shows that both methods have their own advantages in terms of accuracy and ease of use. The use of metaverse technology as an aid in determining Qibla direction has great potential, especially in situations where locations are unfamiliar or access to traditional methods is limited. However, there are several critical factors that need to be considered to ensure the accuracy and legal validity of the use of this technology such as network quality, geographical conditions, and the accuracy of the geospatial data used by the metaverse device.

In addition, although this technology offers intuitive and practical visualizations, it is important to conduct in-depth studies from a sharia perspective so that it can be widely accepted by Muslims. Education and socialization on the workings and benefits of this technology are also needed to increase acceptance and confidence in its use in worship. Overall, the metaverse has the potential to be a practical and efficient solution in helping Muslims determine the Qibla direction with greater confidence, especially in conditions that are less than ideal for traditional methods.

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