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K-NEAREST NEIGHBORS FOR FAST AND ACCURATE QIBLA DIRECTION DETERMINATION

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Abstract

Determining the correct direction of the Qibla is essential for the validity of prayer, but in areas far from the Kaaba, this can be a challenge. While calculating the Qibla azimuth using latitude and longitude is relatively straightforward, traditional methods for obtaining the Qibla direction, such as those provided by the Muhammadiyah Central Leadership's Tarjih Center, are time-consuming and require specialized teams. This paper proposes a recommendation system that uses the K-Nearest Neighbors (K-NN) algorithm to provide an efficient and automated solution for determining the Qibla direction. The system leverages the Google Maps API to obtain geographic coordinates and calculates the Qibla azimuth by applying the Euclidean distance formula between latitude and longitude points. The K-NN method is employed to recommend the nearest mosque or prayer room that is aligned with the correct Qibla direction, based on proximity and geographic data. This approach eliminates the need for a dedicated team and significantly reduces the time required for users to find the correct direction. The system's performance was tested through Black Box testing to ensure all features functioned as expected. User acceptance was measured using the System Usability Scale (SUS), resulting in an average score of 76.33, indicating good usability. Additionally, accuracy testing compared the recommended Qibla direction from 28 mosques and prayer rooms with another established system, yielding an accuracy of 78.57%. These results demonstrate that the proposed K-NN-based recommendation system is both effective and efficient for determining the Qibla direction.
Keywords: Qibla Direction, Recommendation System, K-Nearest Neighbor, Latitude, Longitude

INTRODUCTION

Facing the Qibla is a fundamental requirement for the validity of prayer in Islam. It is essential that Muslims accurately determine the direction of the Kaaba in Mecca during prayer, which is considered the direction of worship. For those living close to the Kaaba, determining the Qibla is relatively straightforward. However, for individuals residing far from Mecca, determining the correct Qibla direction can be challenging. Scholars have long agreed that individuals can determine the Qibla based on geographic knowledge, but it becomes more difficult for those who are unable to visually identify the Kaaba. While facing the Qibla with certainty is acceptable, the precision of this direction enhances the quality and perfection of worship [1][2].
Advancements in technology have made it possible to calculate the Qibla direction with greater accuracy, leveraging systems like the Global Positioning System (GPS). GPS technology, when paired with microcontrollers, enables precise mathematical calculations that determine the Qibla direction in terms of azimuth, based on the user's geographic location [3][4]. However, GPS is susceptible to errors, particularly due to ionospheric interference, which can affect the accuracy of positioning and thus, the calculated Qibla direction [5]. Despite these issues, GPS remains a widely used and effective tool for general navigation and direction-finding.

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Current methods for determining the Qibla direction, such as those provided by the Pusat Tarjih Muhammadiyah, involve manual measurements with devices like the Theodolite. Although highly accurate, this process is time-consuming, requiring reservations and dedicated teams to perform the measurements. For instance, users must wait up to a week to have their Qibla direction measured, which can be impractical for many people. This results in a significant gap between the need for a quick, accessible solution and the services currently available.

To address this gap, this study proposes a novel, automated Qibla direction recommendation system based on the K-Nearest Neighbor (K-NN) algorithm. The system utilizes GPS-based geolocation data and the Google Maps API to calculate the user's current location and the location of nearby mosques or prayer rooms. Using the K-NN method, the system identifies the three closest mosques or prayer rooms and calculates the azimuth direction to each, presenting the most accurate and efficient option for the user. The K-NN algorithm is well-suited to this task, as it has been successfully used in various location-based recommendation systems, achieving high accuracy rates in identifying the closest points based on geographic data [9]. The Google Maps API ensures real-time access to location data, further enhancing the system's reliability and usability by providing up-to-date geographic information.

The proposed system is innovative because it combines modern machine learning techniques (K-NN) with geospatial technologies (GPS and Google Maps API) to create a fast, reliable, and user-friendly solution for determining the Qibla direction. Unlike traditional methods that rely on specialized equipment and personnel, this system automates the process, making it accessible to anyone with a smartphone or other GPS-enabled device. It offers an efficient alternative to manual measurement, providing accurate Qibla direction recommendations in a fraction of the time.

In conclusion, this research contributes a novel approach to Qibla direction determination that leverages modern algorithms and geospatial technologies to improve the efficiency and accessibility of Qibla-related services. The proposed system addresses the limitations of existing methods, offering an innovative solution that is both accurate and easy to use for a wide range of users.

LITERATURE REVIEW

Qibla Direction Measurement

Determining the direction of the Qibla is crucial for the validity of prayer in Islam, particularly for Muslims living in regions far from the Kaaba in Mecca. In areas close to the Kaaba, it is relatively easy to physically orient oneself toward the Qibla, as the Kaaba is directly visible. However, for those located at a significant distance, accurately determining the direction toward the Kaaba involves precise geographic calculations. This process requires determining the position of the Kaaba relative to the individual's location on the Earth's surface, a task that necessitates the application of spherical geometry and the understanding of the Earth's curvature [11].

Since both the Kaaba and the place of prayer are located on the surface of a spherical Earth, calculating the direction from a specific location to the Kaaba involves considering this spherical nature. In regions near the Kaaba, aligning oneself toward it may be done visually, but in distant locations, mathematical calculations based on the Earth's shape and the relative positions of the two points (the place of prayer and the Kaaba) are needed. These calculations rely heavily on geographic coordinates, which are expressed in latitude and longitude.

1. Latitude and Longitude: Latitude is the angular distance north or south of the equator, which is at 0° latitude. It defines a location's position relative to the Earth's horizontal axis. The equator divides the Earth into the northern and southern hemispheres, and the latitude is measured in degrees (°), minutes (‘), and seconds (“). The poles, located at 90°N and 90°S, mark the extremes of latitude.
2. Longitude, on the other hand, defines a location's position east or west of the prime meridian, which is located at 0° longitude in Greenwich, England. Longitude lines run from the North Pole to the South Pole, and they are measured in degrees (°), minutes (‘),

and seconds (“). These two coordinate systems, latitude and longitude, are fundamental in pinpointing any location on Earth, including the Kaaba and the place of prayer [12][13]. Figure 1 illustrates the Earth with lines of latitude, and Figure 2 shows the globe with the prime meridian marking the lines of longitude.

3. Azimuth: In geographic and astronomical contexts, the direction of any object relative to an observation point is described by its azimuth. Azimuth is an angular measurement, often used to define the direction from a specific observation point to the object of interest (in this case, the Kaaba). The azimuth is typically measured in degrees (°), minutes (‘), and seconds (“). It defines the angle between a reference direction, usually true north, and the line extending from the observer to the point of interest, measured clockwise [23][24]. Therefore, the Qibla azimuth represents the angle between true north and the direction towards the Kaaba, as viewed from the observer’s location. The Qibla direction is therefore essentially the azimuth pointing towards the Kaaba, and its calculation is crucial for Muslims who must align themselves toward the Kaaba while praying [16].
4. Methods of Qibla Direction Measurement: Currently, measuring the Qibla direction has become more sophisticated and accurate, leveraging advanced technology such as GPS and theodolites. The theodolite is an instrument used to measure horizontal and vertical angles, which allows for precise alignment with the Kaaba. In combination with tools like GPS (Global Positioning System), the theodolite can help measure the angle of the sun’s azimuth. By determining the sun's azimuth at a given location, one can deduce the true north, which is then used to calculate the Qibla direction in degrees, minutes, and seconds.
5. Using Qibla Tracker Applications: There are now several mobile applications, such as Qibla tracker apps, that help users determine the Qibla direction using the same principles of geographic coordinates and azimuth calculation. These applications typically use the smartphone’s GPS capabilities to determine the user’s precise geographic location (latitude and longitude) and then calculate the Qibla azimuth based on that data. The application will then display the correct direction (often as an arrow or compass), allowing the user to easily align themselves with the Qibla, no matter their distance from Mecca.

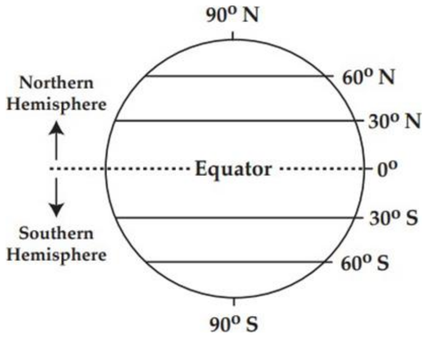

Figure 1 The earth with lines of latitude

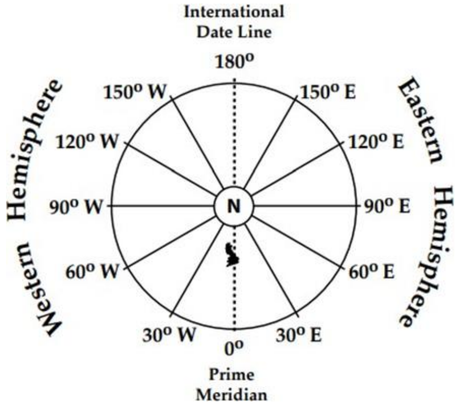

Figure 2 Globes with the prime meridian

Geographic Data and GPS

Global Positioning System (GPS) technology has made a significant impact on positioning accuracy, which is critical for determining Qibla direction in remote areas. GPS provides location data through satellite signals, allowing for precise determination of coordinates (latitude and longitude) with an accuracy range of approximately ±6.4 meters [17]. Several studies have demonstrated the effectiveness of GPS for location tracking in various applications, from vehicle monitoring to online food delivery systems [17]. In the context of Qibla direction, GPS data combined with applications such as Google Maps API can facilitate quick and accurate geographic location identification, offering an accessible and real-time solution.

Pusat Tarjih Muhammadiyah's Qibla Measurement Service

Pusat Tarjih is an institution initiated by the Tarjih and Tajdid Council of the Muhammadiyah Central Leadership in collaboration with Universitas Ahmad Dahlan Yogyakarta.

The Muhammadiyah Central Leadership's Tarjih Center has been providing Qibla direction measurement services using traditional tools, such as the theodolite, which measures the azimuth of the Qibla. Although this method offers high accuracy, it requires a dedicated team and can be time-consuming, with wait times extending up to one week for appointments [18]. This poses a challenge for those who need a quick and reliable method for determining the Qibla direction. The current study aims to overcome these limitations by automating the process and reducing the time and effort required to find the correct Qibla direction.

Recommendation System

Recommendation systems have gained popularity in various fields by providing users with suggestions based on available data. These systems are commonly implemented in e-commerce, media, and service industries, offering personalized recommendations based on user preferences or geographical data [19]. The two main methods used in recommendation systems are collaborative filtering and content-based filtering. Content-based filtering, which is the approach used in this study, recommends items based on the features or attributes of the item itself [20]. In this case, geographic data and proximity to the nearest mosque or prayer room are used to recommend the most accurate Qibla direction for the user.

K-Nearest Neighbors (K-NN) Algorithm

The K-Nearest Neighbors (K-NN) algorithm is a widely used machine learning technique that excels in classification and recommendation tasks by classifying data points based on their proximity to nearby points, using distance metrics such as Euclidean distance [9]. This method has been successfully applied across various domains, such as predicting air quality [21] and recognizing sign language gestures [22]. Given its ability to quickly and efficiently make proximity-based recommendations, K-NN is an ideal choice for recommending the most appropriate Qibla direction in this study. By calculating the Euclidean distance between the user's location and nearby mosques or prayer rooms, the algorithm identifies the most suitable Qibla direction.

In recent years, the K-Nearest Neighbor (KNN) algorithm has gained significant attention for its effectiveness in a range of applications, particularly in bioinformatics, human behavior analysis, and cognitive studies. KNN has been successfully used in EEG-based classification tasks, such as predicting student interest through brain activity during website interactions[28]. A study in Yogyakarta demonstrated the algorithm's capability to classify noisy data with an impressive 92% accuracy. Similarly, KNN has been employed to classify emotional states based on EEG signals, achieving up to 83.33% accuracy. These applications highlight KNN's ability to handle real-time, dynamic data, a feature essential for tasks like Qibla direction determination, which requires precise, spatially-aware classification from fluctuating brainwave signals[29].

Moreover, KNN has proven useful in analyzing brain concentration and cognitive performance, with a study on junior high school students achieving a 94.59% accuracy in predicting concentration levels based on EEG data[30]. Other studies, such as those investigating game addiction and insomnia, also demonstrate KNN's proficiency in handling EEG data to classify attention and mental states. These diverse applications show that KNN is an ideal tool for real-time, multidimensional classification tasks[32-35], including the determination of Qibla direction. By leveraging KNN's ability to classify complex, noisy data, your research on Qibla direction determination can benefit from its speed and accuracy in providing reliable spatial orientation predictions[31].

The choice of K=3 is based on several empirical studies that demonstrate its effectiveness. In a study by Jacob L. Strunk, K=3 performed the best in Diameter Density Prediction using airborne lidar, according to multiple evaluation criteria, suggesting that K=3 optimizes accuracy in spatial-based prediction tasks [21]. Similarly, in Zulfrianto Y. Lamasigi's research on Batik Identification, K=3 yielded an accuracy of 84.88%, significantly higher than K=7 and K=9, which achieved accuracy values of 41.86%. This result emphasizes that K=3 provides superior performance in tasks that require proximity-based classification [22]. Additionally, in Dewinta Aryanie's study on American Sign Language Finger-spelling Recognition, K=3 achieved an impressive accuracy of 99.8%, far surpassing the 28.6% accuracy of K=5. This supports the conclusion that K=3 consistently delivers better performance and accuracy, making it a suitable choice for the recommendation of Qibla directions in this study.

Based on these findings, it is evident that K=3 is a highly effective and accurate choice for proximity-based recommendations, aligning perfectly with the objectives of this research.

Google Maps API

The Google Maps API provides access to geolocation data and mapping functionalities that are crucial for real-time Qibla direction determination. By integrating the API into the system, geographic coordinates of mosques and prayer rooms can be retrieved, and the Qibla azimuth can be calculated efficiently. This enables users to visualize the recommended direction and facilitates user understanding [23]. However, access to Google Maps requires an internet connection, which may limit its availability in certain areas without reliable data access.

Mobile Applications

Mobile applications are software programs developed for mobile devices that have specific functions and are related to hardware, software, and network connectivity [17]. Mobile applications have become ubiquitous tools for providing location-based services. They are increasingly used for a variety of purposes, from food delivery to navigation. The development of mobile applications, particularly using frameworks like Flutter, provides flexibility for creating cross-platform applications that work on both Android and iOS devices [24]. In this research, a mobile application was developed to offer users an easy-to-use interface to determine the Qibla direction, leveraging the technologies discussed above.

Testing and Usability Evaluation

To ensure the reliability, functionality, and user-friendliness of the proposed recommendation system, several testing stages were conducted. These tests aimed to evaluate both the technical performance of the system and its overall usability from the perspective of the end-users.

Black Box Testing

One of the primary tests conducted was Black Box testing, a technique used to verify the system's functionality without requiring knowledge of its internal structure or code [25]. In this testing approach, the focus is solely on the input-output relationship, ensuring that the system behaves as expected when interacting with different types of user inputs. Black Box testing was particularly important to confirm that the recommendation system was accurately calculating the Qibla direction based on the geographical coordinates provided, and that the system responded correctly to various user inputs, such as different locations and search queries. This type of testing helped identify any discrepancies or errors in the system's functionality, ensuring that users could rely on the system for determining the correct Qibla direction.

User Satisfaction and Usability Evaluation

The system's usability was evaluated using the System Usability Scale (SUS), a widely recognized and standardized tool for measuring the ease of use of a system [26]. The SUS involves a set of 10 questions designed to assess user satisfaction with various aspects of the system, such as its intuitiveness, effectiveness, and overall user experience. These questions cover dimensions like the system's ease of navigation, clarity of instructions, and users' willingness to use the system again. The scale is designed to provide a composite score ranging from 0 to 100, where higher scores indicate better usability.

METHODS

This recommendation system utilizes the K-Nearest Neighbors (K-NN) algorithm with K = 3. The choice of K=3 is based on its proven accuracy in prior studies and its alignment with the intended functionality of the application. As discussed in the literature review, K=3 has shown to offer high accuracy in similar applications, which makes it an ideal choice for this system. Additionally, K=3 is well-suited to the nature of the data and the goal of the system, which is to recommend nearby mosques or prayer rooms based on proximity. The calculations use Euclidean distance, with geographic data (latitude and longitude) as the main input.

Data Collection

The development of this system required thorough preparation to ensure proper functionality. Data was collected by directly requesting it from the Muhammadiyah Tarjih Center. A total of 28 data entries were obtained, which include the names of Masjid (mosques) and Musholla (prayer rooms), along with their corresponding latitude, longitude, and Qibla azimuth values. As shown in Table 1, the data entries for masjids and prayer rooms include essential details such as their names, locations, and capacities, which are crucial for the Qibla direction determination process.

Table 1. Data Entries of Masjid and Prayer Rooms

No.	Name	Latitude	Longitude	Qibla Azimuth
1	*Masjid Abdurrahman*	-7.68267222	109.845025	294° 48' 46.82"
2	*Masjid Al- Barokah*	-7.74070833	110.5263722	294° 39' 33.92"
3	*Masjid Al- Hasanah*	-7.77902222	110.3036167	294° 43' 23.07"
4	*Masjid Al Hidayah*	-7.84025833	110.3660222	294° 43' 22.01"
5	*Masjid Al- Hikmah*	-7.74046111	110.3517417	294° 42' 07.36"
6	*Masjid Al-Huda*	-7.64447222	110.3576389	294° 43' 02.82"

7	*Masjid Al- Ikhlas jl Klepu Pitaroh*	-7.70550556	109.8432639	294° 34’ 26.97”
8	*Masjid Al- Ikhlas*	-7.72810000	109.002775	294° 48’ 45.59”
9	*Masjid Al- Ilham*	-7.73773056	110.3521667	294° 42’ 04.68”
10	*Masjid Al-Iman*	-7.67730000	110.3614778	294° 40’ 41.07”
11	*Masjid Al-Insani*	-7.76374444	110.2969278	294° 43’ 16.46”
12	*Masjid Al Mutsanna Bin Haritsah*	-7.93533889	110.3713528	294° 44’ 40.01”
13	*Masjid Baitul Qohhar UII*	-7.78179444	110.3747833	294° 42’ 23.61”
14	*Masjid Hajjah Yuliana*	-7.80699722	110.267325	294° 44’ 20.61”
15	*Masjid Jabir Bin Abdilah*	-7.79166667	110.4086111	294° 42’ 08.97”
16	*Masjid Jendral Soedirman*	-7.92960278	110.3886306	294° 44’ 19.32”
17	*Masjid Nurul Huda*	-7.75455833	110.4980083	294° 40’ 11.01”
18	*Masjid Nurul Islam*	-7.75508333	110.3648972	294° 42’ 08.69”
19	*Masjid Nurul Mubin*	-7.81291667	110.352525	294° 43’ 10.14”
20	*Masjid Raya Al-Muttaqun*	-7.75537500	110.4952028	294° 40’ 14.02”
21	*Masjid Semaki Gede*	-7.80030556	110.3851667	294° 42’ 30.24”
22	*Masjid Shirothol Mustaqim*	-7.64741944	110.361725	294° 40’ 37.07”
23	*Masjid Tanjung Anom*	-7.75794722	110.2632972	294° 43’ 41.14”
24	*Masjid Tunas Harapan*	-7.92149722	110.3851278	294° 42’ 15.55”
25	*Mushalla Al-Hikmah*	-7.82912500	110.3634833	294° 43’ 14.39”
26	*Mushallah Al- Huda*	-7.65071667	110.360325	294° 40’ 41”
27	*Mushalla Al-Hidayah*	-7.76742222	110.3972139	294° 41’ 52.35”
28	*Masjid Al_Mustaqim*	-7.81425444	110.6432036	294° 38’ 54.4”

Recommendation Flow Design

The K-NN method was employed to design the recommendation flow, which outlines how the system generates suggestions. The K-NN algorithm is a classification technique that classifies a data point based on the proximity of other data points. The goal is to estimate the likelihood that a data point belongs to a particular class by considering the group to which the nearest data points belong. Euclidean Distance is commonly used to calculate the proximity between points.

As illustrated in Figure 3, the flowchart of the K-nearest neighbor process outlines the steps involved in the algorithm, from data preprocessing to classification. The steps involved in implementing the K-NN method include:

1. Determine the K value (the number of nearest neighbors).
2. Calculate the Euclidean distance for each query point in relation to the sample data.
3. Collect the K-Nearest Neighbors.
4. The new object is classified based on the closest neighbors, with the classification determined by majority vote.

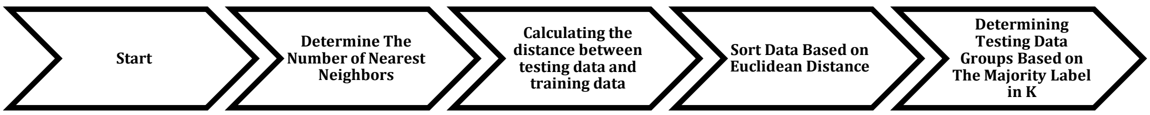

Figure 3. Flowchart of K-nearest neighbor Process

The pseudocode below provides a more detailed breakdown of the K-NN process:

Pseudocode for K-NN Process:

```
Input: Training data (X_train, y_train), Test data (X_test), K
Output: Predicted labels (y_pred)

For each test_point in X_test:
    distances = []
    For each train_point in X_train:
        dist = EuclideanDistance(test_point, train_point)
        distances.append((dist, train_point_label))
    End For

    # Sort distances in ascending order
    sorted_distances = sort(distances)

    # Select K nearest neighbors
    neighbors = sorted_distances[:K]

    # Determine the majority class
    prediction = MajorityVote(neighbors)

    # Store prediction
    y_pred.append(prediction)
End For
Return y_pred
```

This algorithm calculates the K nearest neighbors based on Euclidean distance and assigns a predicted label based on the majority class of the nearest neighbors.

Azimuth Calculation Example

For this research, we demonstrate the calculation of the Qibla direction using the K-NN method. Consider a case where we use 6 out of the 28 data points. As shown in Table 2, the data of Qibla Azimuth provides the necessary geographical references to determine the direction of the Qibla based on various locations. With a location defined by latitude = -7.809375154794347 and longitude = 110.27984525874403, the system computes the Euclidean distance to each of these six locations.

Table 2. Data of Qibla Azimuth

Name	Latitude	Longitude	Qibla Azimuth
Masjid Al Mutsanna Bin Haritsah	-7.93533889	110.3713528	294° 44’ 40.01”
Masjid Hajjah Yuliana	-7.80699722	110.267325	294° 44’ 20.61”
Masjid Jendral Soedirman	-7.92960278	110.3886306	294° 44’ 19.32”
Masjid Al Hidayah	-7.84025833	110.3660222	294° 43’ 22.01”
Mushalla Al-Hikmah	-7.829125	110.3634833	294° 43’ 14.39”
Masjid Al-Huda	-7.64447222	110.3576389	294° 43’ 02.82”

Based on the data above, the Qibla azimuth can be determined from a location with latitude -7.809375154794347 and longitude 110.27984525874403, using K=3. These coordinates can be utilized to calculate the distance to the six data points listed below. Table 3 presents the result of the calculation of nearest neighbors, highlighting the points identified based on their proximity to the data points in question.

The following is the calculation:

Data 1:

$$distance1 = \sqrt{(-7.809375154794347 - (-7.93533889))^2 + (110.27984525874403 - 110.3713528)^2} = 0.1556935859$$

Data 2:

$$distance2 = \sqrt{(-7.809375154794347 - (-7.80699722))^2 + (110.27984525874403 - 110.267325)^2} = 0.01274407521$$

Data 3:

$$distance3 = \sqrt{(-7.809375154794347 - (-7.92960278))^2 + (110.27984525874403 - 110.3886306)^2} = 0.1621386207$$

Data 4:

$$distance4 = \sqrt{(-7.809375154794347 - (-7.84025833))^2 + (110.27984525874403 - 110.3660222)^2} = 0.1556935859$$

Data 5:

$$distance5 = \sqrt{(-7.809375154794347 - (-7.829125))^2 + (110.27984525874403 - 110.3634833)^2} = 0.09154362739$$

Data 6:

$$distance6 = \sqrt{(-7.809375154794347 - (-7.64447222))^2 + (110.27984525874403 - 110.3576389)^2} = 0.1823316443$$

Table 3. Result of six nearest points

Name	Latitude	Longitude	Distance to new data
Masjid Hajjah Yuliana	-7.80699722	110.267325	0.012744075
Mushalla Al-Hikmah	-7.829125	110.3634833	0.091543627
Masjid Al Mutsanna Bin Haritsah	-7.93533889	110.3713528	0.155693586
Masjid Al Hidayah	-7.84025833	110.3660222	0.155693586
Masjid Jendral Soedirman	-7.92960278	110.3886306	0.162138621
Masjid Al-Huda	-7.64447222	110.3576389	0.182331644

Based on the results of the calculations carried out, the three nearest neighbors identified through this calculation are: the Hajjah Yuliana Mosque with an azimuth of 294° 44', the Al-Hikmah Mushalla with an azimuth of 294° 43', and the Al Mutsanna Bin Haritsah Mosque with an azimuth of 294° 44'. The most likely Qibla azimuth for the new location is 294° 44', derived from the proximity of these three nearest points.

Data Modelling
A data model was created to convert the database into a format suitable for Firebase. As shown in Table 4, the table outlines the key attributes of the data model, which are essential for structuring the data effectively for Firebase:

Table 4. Data Model

Entity	Attribute	Data Type	Information
coordinate_data	Id	*String*	*Primary Key*
	name	*String*	-
	latitude	*Number*	-
	longitude	*Number*	-
	degree	*Number*	-
	minute	*Number*	-
	second	*Number*	-

System Development Stages
The system development was divided into the following stages:

1. **System Development Requirements**
   Software Requirements:
   a. The system development requires specific software, including:
      i. Operating System: Windows 11
      ii. Development Tools: Visual Studio Code, Android Studio, Firebase, Flutter, Google Chrome.
   b. For debugging, the system requires Android 12 or later.

   Hardware Requirements:
   a. Computer: Processor with 64-bit quad-core CPU, 8GB RAM, monitor, mouse, keyboard, integrated graphics card.
   b. Android Device: Octa-core CPU (max 2.00GHz), 6GB RAM, and 2GB available storage.

2. **Building the K-NN Model (Pre-Development)**
   The K-NN model was constructed to identify the nearest mosque to the user's location, with K = 3. It was implemented using Flutter and displayed on the screen. The system is connected to Firebase, making the data accessible online. As shown in Figure 4, the result is displayed on the Android screen, illustrating the functionality of the model.

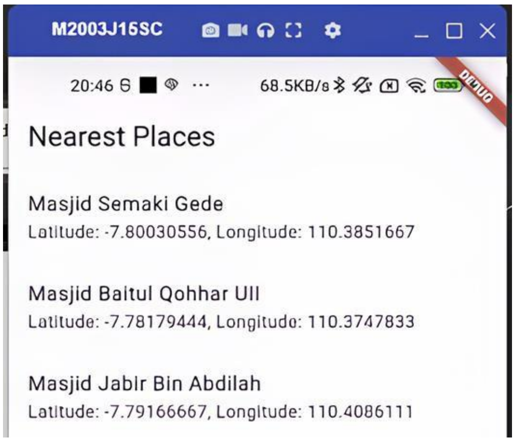

Figure 4. Visualization on Android screen

After developing the model, visual evaluation was conducted using Google Maps to ensure the correct sorting of mosques by proximity. The evaluation confirmed that the closest mosque, Semaki Gede Mosque, was correctly identified as the nearest point. As shown in Figure 5, three data points are displayed on the map, illustrating the result of the evaluation.

Figure 5. Three data displayed on Maps

3. **Full System Development**
   The final development phase involved implementing the system based on the designed interface. The application, built with Flutter, allows users to view the Qibla direction via a compass, as well as a list of the three nearest mosques sorted by proximity. The app utilizes Dart as the programming language, Visual Studio Code as the text editor, and Firebase for data hosting.

RESULT AND DISCUSSIONS

The Recommendation System for Determining Qibla based on the K-Nearest Neighbors (K-NN) algorithm has successfully demonstrated its functionality. When the application is launched, the initial display shows a map generated using the Google Maps API. Upon pressing the “Current Location” button located at the bottom left, the system immediately centers the map on the user’s current location, after requesting location permissions. The system then identifies the three closest mosques or mushalas and displays them. A Compass widget is centrally located in the application, pointing to the Qibla azimuth direction of the nearest mosque, based on the first data point.
Figure 6 illustrates the application interface, which includes several key features:

1. “RSD Qibla” widget: Displayed at the top of the application, indicating the Recommendation System Determining Qibla.
2. Clock Widget: Positioned beneath the title, showing the current time.
3. Compass Widget: Positioned in the center, it shows the Qibla azimuth direction corresponding to the closest mosque.
4. Zoom and Scroll: The map view can be zoomed in and out using the buttons at the bottom right or with a two-finger pinch gesture.
5. Location Button: A button on the bottom left prompts the user to grant location permissions, enabling the map to move to the user’s current position and find the closest data points.

The application’s background uses the Google Maps API, ensuring a familiar map interface. However, it requires an active internet connection for retrieving map data and mosque locations, and is currently limited to the Yogyakarta area, making it unsuitable for use outside this region.

Additionally, the system displays only three nearby mosque recommendations, which may limit its usefulness in areas with more mosques.

Figure 6. Application Interface

Research Limitations
Several limitations have been identified:

1. Internet Dependency: The system requires a stable internet connection to function, as it relies on Google Maps and external databases to retrieve location and mosque data.
2. Geographical Limitation: The system is restricted to Yogyakarta and is not currently designed to work in other locations.
3. Limited Data Display: Only the three closest mosques are shown, limiting the system's ability to recommend more options in densely populated areas.

Black Box Testing
To assess whether the system's features work as expected, Black Box Testing was performed. This testing, conducted by Ir. Ahmad Azhari, S.Kom., M.Eng., confirmed that the system's core functions operate as intended, with the results that can be seen in the Table 5.

Table 5. Black Box Test Result

No.	Testing Scenario	System Evaluation		Correct Result
		Correct	***Wrong***	
1	Displays the Google Maps interface along with all widgets/features.	Successfully displays the Google Maps Interface, and all features without error.	an error occurred.	100%

2	Swipe the screen to change the position display on Google Maps.	Successfully moved according to the position of the swipe.	Does not move at all.	100%
3	Press the "+" and "-" buttons to zoom in and out of the Maps display.	Successfully zoom in and out of Maps display.	Cannot zoom in and out on Maps.	100%
4	Displays 28 data points right on the Maps location.	Successfully displayed 28 data according to coordinates on Maps.	Data does not appear in Maps.	100%
5	Pressing the current location button will change the Maps camera position to the user's current position.	Successfully displayed the user's current location point.	Maps camera does not move and cannot find current Location point.	100%
6	Displays the three closest data lists.	Successfully displays three lists of nearby data, sorted from the closest to the furthest.	Does not display the three nearest data lists.	100%
7	Displays the compass direction according to the topmost Qibla azimuth data.	Successfully displays the Compass whose azimuth direction of the Qibla matches the first data.	The compass does not appear, and does not show the direction of the first data.	100%
8	Displays the clock feature.	Successfully displays the clock according to the current time.	The clock does not display.	100%

The test results showed that the Google Maps interface displayed without errors, and map positioning changed correctly when the user swiped the screen. The zoom in/out feature functioned properly, and the current location functionality accurately centered the map on the user's position. Additionally, the application successfully displayed the three closest data points, along with the Compass widget and clock. All tests returned 100% success, demonstrating that the system functions as designed without any issues.

System Usability Scale (SUS)
SUS testing is conducted to determine or measure the level of usability of the system from the user's perspective. Furthermore, users are asked to complete a questionnaire via Google Form based on their experience when using the Qibla Determining Recommendation System. The questionnaire contains 10 questions that must be answered by 15 respondents, including the following question representing in Table 6.

Table 6. SUS Questions

No.	Questions
1	I think that a system like this is very helpful.
2	I need to practice on someone before using this system
3	I think that the features in this system are working as they should.
4	I think this system is too complicated to use.
5	I think that there is no hassle in using this system.
6	I think this system confuses the user.
7	I think that even a lay person can easily use this system.
8	I think that I will use this system in the future.
9	I think this system is quite easy to use.
10	I think the features are not working properly yet

Testing was conducted by distributing a questionnaire to the respondents. After obtaining the system test data, the calculation process was carried out following specific rules. The method for calculating the results of the SUS questionnaire is outlined in Table 7. This data requires processing using several conditions. First, for each odd-numbered question, the respondent's answer scale is reduced by 1 and 3, then the number for each respondent is multiplied by 2.5, as shown in Table 8. The results of the SUS calculation process are guided by the SUS guidelines in Figure 7.

Table 7. SUS Data Obtained

Participant ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	5	1	5	2	1	1	5	5	5	1
2	5	4	5	2	4	1	4	5	4	5
3	5	2	5	2	5	2	5	2	4	1
4	5	3	4	2	5	1	3	4	4	2
5	5	3	5	2	4	2	5	5	5	3
6	5	5	5	5	5	5	5	5	5	5
7	5	4	5	2	5	1	5	5	5	1
8	3	3	4	2	3	2	2	3	2	1
9	5	1	4	2	5	1	4	5	5	2
10	4	2	4	4	2	2	4	5	4	2
11	4	4	4	4	4	4	4	4	4	4
12	4	4	4	2	3	2	5	4	4	2
13	5	1	5	1	5	1	5	5	5	1
14	5	1	5	2	1	1	5	5	5	1
15	5	4	5	2	4	1	4	5	4	5

Table 8. Calculated SUS Score

Participant ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	4	1	4	2	0	1	4	5	4	1
2	4	4	4	2	3	1	3	5	3	5
3	4	2	4	2	4	2	4	2	3	1
4	4	3	3	2	4	1	2	4	3	2
5	4	3	4	2	3	2	4	5	4	3

6	4	5	4	5	4	5	4	5	4	5
7	4	4	4	2	4	1	4	5	4	1
8	2	3	3	2	2	2	1	3	1	1
9	4	1	3	2	4	1	3	5	4	2
10	3	2	3	4	1	2	3	5	3	2
11	3	4	3	4	3	4	3	4	3	4
12	3	4	3	2	2	2	4	4	3	2
13	4	1	4	1	4	1	4	5	4	1
14	4	1	4	2	0	1	4	5	4	1
15	4	4	4	2	3	1	3	5	3	5
Sum	55	42	54	36	41	27	50	67	50	36
x 2.5	137.5	105	135	90	102.5	67.5	125	167.5	125	90
Average	1145/15=76.333									

SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51 – 68	D	Poor
< 51	F	Awful

Figure 7. SUS guidelines

The average SUS score obtained was 76.33, which is considered "Good" based on the SUS guidelines. This indicates that the system is user-friendly and well-received by users. Respondents reported that the system was intuitive, and all features functioned as expected without causing confusion or difficulty.

Accuracy Testing

Accuracy Testing was conducted by comparing the Qibla azimuth values from 28 mosque and mushala data points with those from arahrkiblat.id. The azimuth values, initially presented in degrees, minutes, and seconds, were converted into decimal format for easier comparison. The results showed that 22 out of 28 data points matched exactly, giving an accuracy rate of 78.57%. The discrepancies were due to minor differences in how azimuth values were rounded or measured.

Accuracy testing was carried out by comparing the direction of the Qibla from 28 data points from mosques and mushalas with another system, arahkiblat.id. The data was converted from degrees, minutes, and seconds to decimals to facilitate accuracy calculations, as shown in Figure 8 and Figure 9. These figures illustrate the comparison between the two systems, providing a clear view of the alignment between the Qibla directions.

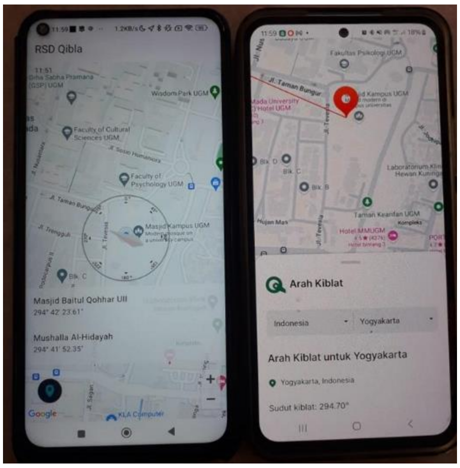

Figure 8. Data Comparison to *arahkiblat.id*

Figure 9. Data Comparison to *onlineconversion*

Table 9. Qibla Direction Accuracy Comparison

No.	Name	Qibla Azimuth	Decimal	*arahkiblat.id*'s data
1	*Masjid Abdurrahman*	294° 48’ 46.82”	294.81	294.81
2	*Masjid Al- Barokah*	294° 39’ 33.92”	294.66	294.66
3	*Masjid Al- Hasanah*	294° 43’ 23.07”	294.72	294.72
4	*Masjid Al Hidayah*	294° 43’ 22.01”	294.72	294.70
5	*Masjid Al- Hikmah*	294° 42’ 07.36”	294.70	294.70
6	*Masjid Al-Huda*	294° 43’ 02.82”	294.72	294.68
7	*Masjid Al- Ikhlas jl Klepu Pitaroh*	294° 34’ 26.97”	294.57	294.82
8	*Masjid Al- Ikhlas*	294° 48’ 45.59”	294.81	295.04
9	*Masjid Al- Ilham*	294° 42’ 04.68”	294.70	294.70
10	*Masjid Al-Iman*	294° 40’ 41.07”	294.68	294.68
11	*Masjid Al-Insani*	294° 43’ 16.46”	294.72	294.72
12	*Masjid Al Mutsanna Bin Haritsah*	294° 44’ 40.01”	294.74	294.74
13	*Masjid Baitul Qohhar UII*	294° 42’ 23.61”	294.71	294.71
14	*Masjid Hajjah Yuliana*	294° 44’ 20.61”	294.74	294.74
15	*Masjid Jabir Bin Abdilah*	294° 42’ 08.97”	294.70	294.70

16	*Masjid Jendral Soedirman*	294° 44’ 19.32”	294.74	294.74
17	*Masjid Nurul Huda*	294° 40’ 11.01”	294.67	294.67
18	*Masjid Nurul Islam*	294° 42’ 08.69”	294.70	294.70
19	*Masjid Nurul Mubin*	294° 43’ 10.14”	294.72	294.72

The Recommendation System for Determining Qibla has proven to be an effective and reliable tool for determining the Qibla direction in Yogyakarta. The integration with Google Maps provides an intuitive user interface, while the K-NN algorithm successfully recommends the nearest mosques. The System Usability Scale score of 76.33 indicates that the system is well-received by users, and the application was able to achieve 78.57% accuracy in its Qibla direction recommendations compared to arahrkiblat.id.

Despite its high usability and accuracy, there are areas for improvement. The system could expand its coverage beyond Yogyakarta, increasing its utility for a broader audience. Additionally, the limited number of recommendations (only three mosques) could be expanded to offer more choices in areas with higher mosque density. Lastly, enhancing offline capabilities would improve the system’s reliability, particularly for users without an active internet connection.

CONCLUSIONS

The Recommendation System for Determining Qibla using the K-Nearest Neighbors algorithm has been successfully developed and implemented. The system provides accurate and reliable Qibla direction recommendations, with the ability to display the nearest mosques and their corresponding Qibla azimuth directions. The system’s performance in Black Box Testing showed 100% success, confirming that all features function as intended. The SUS score of 76.33 indicates that users find the system user-friendly and effective. The accuracy testing showed a 78.57% match with the arahrkiblat.id system, highlighting the reliability of the Qibla direction data. While the system performs well, further improvements could include expanding geographical coverage, offering more recommendations, and providing offline functionality. Overall, the system is a valuable tool for determining Qibla directions in Yogyakarta, with the potential for future enhancements to broaden its reach and improve its accuracy.

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