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# The implementation of ibn al-Haytham's method for determining qibla direction using raspberry Pi

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## Abstract

Ibn al-Haytham or better known as Alhazen (965-1040 AD) was a great Muslim scientist who mastered many disciplines. One of his works entitled "Qawl fi Samt al-Qibla bi al-Hisab" describes a mathematical method for determining the direction of Qibla. In this paper, Ibn al-Haytham's algorithm is modified, thus the algorithm can determine the Qibla direction on the entire surface of the globe. Then, Ibn al-Haytham's mathematical method is compared with modern spherical trigonometry methods and our previous research using al-Biruni's method. The computational results show that all methods have the same accuracy, and show that ibn al-Haytham's method is still relevant. Therefore, the modified ibn al-Haytham method algorithm was implemented to develop a Qibla direction device and interface based on Raspberry Pi 4, GPS module, digital compass, and Processing 3 software. The implementation results show that the device can display the Qibla direction interface according to numerical calculations with high accuracy, real-time, and dynamic interface.

## 1. Introduction

Ibn al-Haytham has a complete name is Abu Ali al-Hasan ibn al-Hasan ibn al-Haytham (965-1040 M), but almost all people in the world knew him as "Alhazen" who is taken from his first name, namely "al-Hasan" [1]. Ibn al-Haytham is a Muslim scientist who mastered many scientific disciplines, such as optics, mathematics, astronomy, philosophy, and engineering. Ibn al-Haytham was the first scientist to combine the mathematical analysis method with the experimental method which underlies the birth of the "Scientific Method". In the astronomy field, Ibn al-Haytham has a method to determine Qibla direction. The method can help Muslims who are far away from Kaaba (in Makkah, Saudia Arabia) to do their prayer or other worship. Ibn al-Haytham's work of determining Qibla direction has been written in *Qawl fi Samt al-Qibla bi al-Hisab* (now, the manuscript stored on Ms. Or. 2970, ff. 4a-11b, Staatsbibliothek Zu Berlin). Besides Ibn al-Haytham, there are other Muslim scientists who contribute in determining Qibla direction: al-Biruni [2][3][4][5] Abu al-Wafa [6][7], al-Khwarizmi [8], Ibn Mu'adh [9][10], al-Nayrizi [11], al-Quhi [12], and others [13][14].

The methodology for determining Qibla direction, Muslim scientists in the classic era mostly use mathematical methods. Thus, the method needed geographical coordinate data of Kaaba and a location which is want to know the Qibla direction. In that era, Muslim scientists (astronomers, navigators, and astrologers) need an astronomical instrument to determine a geographical coordinate (latitude and longitude) of a location named Astrolabe. Besides can determine a coordinate of a location, Astrolabes are usually used to locate and predict the positions of the sun, moon, planets, stars, and others. With the rapid development of technology, Astrolabe has been replaced with the technology named Global Positioning System or GPS. This technology is integrated with a satellite, so that, the latitude and longitude of a location can be accessed easily in real-time, anytime, and everywhere. Researchers have been applied GPS in many fields, such as navigation [15], attendance system [16][17], real-time tracker [18][19], Qibla Direction [4][5][20][21][22] and others [23]. In Qibla Direction development, some researchers combine GPS with other technology, so that it can be used on any device, for example, mobile Qibla Direction [24][25], microcontroller [4][5][20][21][22], and others [10][26].

In our previous research, we have been published the determination of Qibla direction using al-Biruni's method [4][5]. The Qibla direction device in our previous research is based on a microcontroller, thus the interface can only show a number. In this paper, we are studying and analyzing Ibn al-Haytham's method to determine the Qibla direction of a Location based *Qawl fi Samt al-Qibla bi al-Hisab*. Ibn al-Haytham's method is modified, thus the algorithm can determine the Qibla direction on the entire surface of the globe. The computation analysis result compared with the modern spherical trigonometry method and al-Biruni's method from our previous method [4][5]. Then, the ibn al-

Haytham's method algorithm is implemented to develop a Qibla direction device and interface based on Raspberry Pi 4, digital GPS, digital compass, and Processing 3 software. Thus, the device can show the Qibla direction with high accuracy, real-time, and dynamic interface (besides showing a number the interface can direct a user to face Qibla, and other features).

The paper is organized as follows. In section 2 describes the theoretical background to determine Qibla direction using the al-Haytham's method and modern spherical trigonometry method. In section 3 describes the research system design. In section 4 describes the results and discussion of the research. Finally, in section 5 the concluding remarks are given.

## 2. Theoretical Background

This section explains the determination of Qibla direction of a Location based Ibn al-Haytham's method and the modern method (using spherical trigonometry method).

### 2.1 The Determination of Qibla Direction based Ibn al-Haytham's method from Qawl fi Samt al-Qibla bi al-Hisab

The illustration of Ibn al-Haytham's method for determining the azimuth of Qibla is shown in Figure 1.

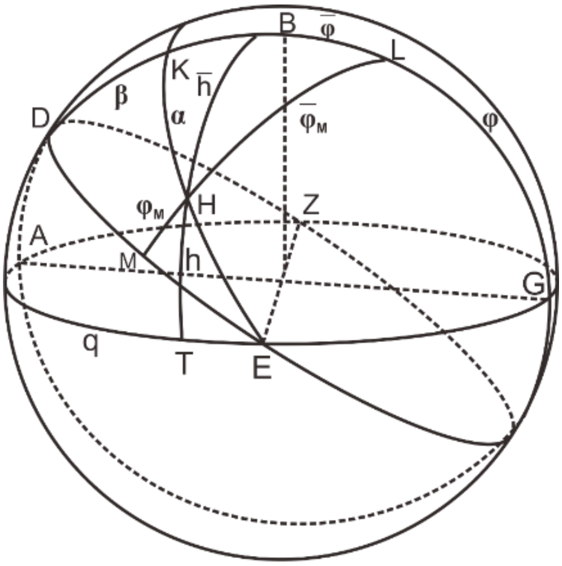



*Figure 1. The Illustration of Ibn al-Haytham's Method from* Qawl fi Samt al-Qibla bi al-Hisab *for Determining Azimuth of Qibla in Baghdad*

Ibn al-Haytham used Menelaus' Theorem to prove his method. The following is a proof of the Qibla direction method made by ibn al-Haytham:

**Applying Menelaus' Theorem to the spherical triangle *HEM***, with *DKL* as the transverse of this triangle, we get Equation 1.

$$\frac{\sin ED}{\sin DM} = \frac{\sin EK}{\sin KH} \times \frac{\sin HL}{\sin LM} \tag{1}$$

If $EK = ED = 90^{\circ}$, we have $\sin KH$ as the Equation 2.

$$\sin KH = \frac{\sin DM \times \sin HL}{\sin LM} \tag{2}$$

For conditions, $DM = \Delta\lambda$, $HL = \bar{\varphi}_M$, and $LM = 90^{\circ}$, then obtained Equation 3.

$$KH = \arcsin \frac{\sin \Delta\lambda \times \sin \bar{\varphi}_M}{R} \tag{3}$$

According to ibn al-Haytham's definition, then we get the first arc of $\alpha$ shown in Equation 4.

$$\alpha = KH = \arcsin \frac{\sin \Delta\lambda \times \sin \bar{\varphi}_M}{R} \tag{4}$$

is the first arc of $\alpha$.

**Applying Menelaus theorem to the spherical triangle *LKH***, with *DME* as the transverse of this triangle, we get Equation 5.

$$\frac{\sin DL}{\sin DK} = \frac{\sin LM}{\sin MH} \times \frac{\sin EH}{\sin EK} \tag{5}$$

If $LM = LD = 90^{\circ}$, we have $\sin DK$ as the Equation 6.

$$\sin DK = \frac{\sin MH \times \sin KE}{\sin EH} \tag{6}$$

For conditions, $MH = \varphi_M$, $\sin EH = \sin \bar{\alpha}$, and $KE = 90^{\circ}$, then obtained Equation 7.

$$DK = \arcsin \frac{\sin \varphi_M \times R}{\sin \bar{\alpha}} \tag{7}$$

According to ibn al-Haytham's definition, then we get the second arc of $\beta$ shown in Equation 8.

$$\beta = DK = \arcsin \frac{\sin \varphi_M \times R}{\sin \bar{\alpha}} \tag{8}$$

$\beta$ is the second arc.

From the explanation it is found that Ibn al-Haytham defines two arcs shown in Equation 9 and Equation 10.

$$\alpha = \arcsin \left( \frac{\sin \Delta\lambda \times \sin \bar{\varphi}_M}{R} \right) \tag{9}$$

$$\beta = \arcsin \left( \frac{\sin \varphi_M \times R}{\sin \bar{\alpha}} \right) \tag{10}$$

Where $\varphi$ represents the latitude of a location, $\varphi_M$ denotes the latitude of the Kaaba in Mecca, $\lambda_L$ represents the longitude of a location, $\lambda_M$ denotes the longitude of the Kaaba in Mecca. $\Delta\lambda$ is the difference of longitude between the location and the Kaaba, $\bar{\varphi}_M = 90^{\circ} - \varphi_M$ is the complement of the latitude of the Kaaba, $\bar{\alpha} = EH = 90^{\circ} - \alpha$ is the complement of $\alpha$, $R = \sin 90^{\circ}$ is represents the radius of the base circle which is numeric calculated using the sine function, $R = 60$ used for sexagesimal numbers, dan $R = 1$ used for decimal numbers. Then, to obtain $AK = \gamma$ (gamma), $q$ (azimuth), and Qibla direction from the North Pole of earth reference, we must take attention to the requirement shown in Table 1.

*Table 1. Qibla direction of location from the north pole of earth reference using ibn al-Haytham method.*

| No | Requirement | $AK = \gamma$ | $AT = q$ | Qibla Logic Against North | Qibla Direction (from North) |
|---|---|---|---|---|---|
| 1 | $\varphi > 0$<br>$\Delta\lambda < 90°$<br>$\beta = \varphi$ | - | $q$ face to West/East | $\lambda_L > \lambda_M$ | 270 |
| | | | | $\lambda_L < \lambda_M$ | 90 |
| 2 | $\varphi > 0$<br>$\Delta\lambda < 90°$<br>$\beta > \varphi$ | $\bar{\varphi} + \beta$ | $q = \sin^{-1}\left( \frac{\sin \alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin \bar{\alpha} \cdot \sin \gamma}{R}\right)\right)} \right)$ | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| | | | | $q = 0$ | 0 |
| 3 | $\varphi > 0$<br>$\Delta\lambda < 90°$<br>$\beta < \varphi$ | $\bar{\varphi} + \beta$ | $q = \sin^{-1}\left( \frac{\sin \alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin \bar{\alpha} \cdot \sin \gamma}{R}\right)\right)} \right)$ | - | $180 + q$ |

| | | | | | |
|---|---|---|---|---|---|
| 4 | $\varphi > 0$<br>$\Delta\lambda > 90°$<br>$\beta = \bar{\varphi}$ | - | $q = \alpha$ | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| 5 | $\varphi > 0$<br>$\Delta\lambda > 90°$<br>$\beta < \bar{\varphi}$ | $\bar{\varphi} - \beta$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| 6 | $\varphi > 0$<br>$\Delta\lambda > 90°$<br>$\beta > \bar{\varphi}$ | $\beta - \bar{\varphi}$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | $q > 0$<br>$-\beta = \bar{\varphi}$ | $180 + q$ |
| | | | | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| 7 | $\varphi > 0$<br>$\Delta\lambda = 90°$ | $\varphi_M$ | $q = \sin^{-1}\left(\frac{\sin\bar{\varphi}_M \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\varphi\cdot\sin\gamma}{R}\right)\right)}\right)$ | - | $360 - q$ |
| 8 | $\varphi < 0$<br>$\Delta\lambda > 90°$<br>$\beta = \varphi$ | - | $q$ face to West/East | $\lambda_L > \lambda_M$ | 270 |
| | | | | $\lambda_L < \lambda_M$ | 90 |
| 9 | $\varphi < 0$<br>$\Delta\lambda > 90°$<br>$\beta > \varphi$ | $\bar{\varphi} - \beta$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | $q > 0$<br>$-\beta = \varphi$ | 270 |
| | | | | $q < 0$<br>$\varphi \le -\varphi_M$<br>$\gamma > 90$ | $180 + q$ |
| | | | | $q < 0$<br>$\gamma < 153$ | $-q$ |
| | | | | $q > 0$<br>$\varphi \le -\varphi_M$<br>$\gamma > 90$ | $180 + q$ |
| | | | | $q < 90$<br>$\gamma < 153$ | $360 - q$ |
| 10 | $\varphi < 0$<br>$\Delta\lambda > 90°$<br>$\beta < \varphi$ | $\bar{\varphi} + \beta$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | - | - |
| 11 | $\varphi < 0$<br>$\Delta\lambda < 90°$<br>$\beta = \bar{\varphi}$ | - | $q = \alpha$ | | |
| 12 | $\varphi < 0$<br>$\Delta\lambda < 90°$<br>$\beta < \bar{\varphi}$ | $\bar{\varphi} + \beta$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| | | | | $q = 0$ | 0 |
| 13 | $\varphi < 0$<br>$\Delta\lambda < 90°$<br>$\beta > \bar{\varphi}$ | $\beta - \bar{\varphi}$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | - | - |
| 14 | $\varphi < 0$<br>$\Delta\lambda = 90°$ | $\varphi_M$ | $q = \sin^{-1}\left(\frac{\sin\bar{\varphi}_M \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\varphi\cdot\sin\gamma}{R}\right)\right)}\right)$ | - | $360 - q$ |
| 15 | $\varphi = 0$<br>$\Delta\lambda < 90°$ | $\bar{\beta}$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| 16 | $\varphi = 0$<br>$\Delta\lambda > 90°$ | $\bar{\beta}$ | $q = \sin^{-1}\left(\frac{\sin\alpha \times R}{\sin\left(90 - \sin^{-1}\left(\frac{\sin\bar{\alpha}\cdot\sin\gamma}{R}\right)\right)}\right)$ | $q > 0$ | $360 - q$ |
| | | | | $q < 0$ | $-q$ |
| 17 | $\varphi = 0$<br>$\Delta\lambda = 90°$ | - | $q = \bar{\varphi}_M$ | - | $360 - q$ |

For the special condition, in another word the location opposite the Kaaba equator, that place become special location. Because people can face Kaaba anywhere. The requirement for the special condition shown in Table 2.

*Table 2. Special Conditions of Qibla direction*

| Special Conditions | No | Require-ment | $AK = \gamma$ | Qibla Direction |
|---|---|---|---|---|
| $\varphi = -\varphi_M$<br>$L = -(180 - L_M)$ | 9 | $\varphi < 0$<br>$\Delta L > 90°$<br>$\beta > \varphi$ | $\bar{\varphi} - \beta$ | Anywhere |

### 2.2 The Determination of Qibla Direction based Modern Spherical Trigonometry Method

Figure 2 is an illustration to determining the Qibla direction of a Location using the Spherical trigonometry method [28][29], the equation is shown in Equation 11, and the "arctan2" equation is described in Equation 12.

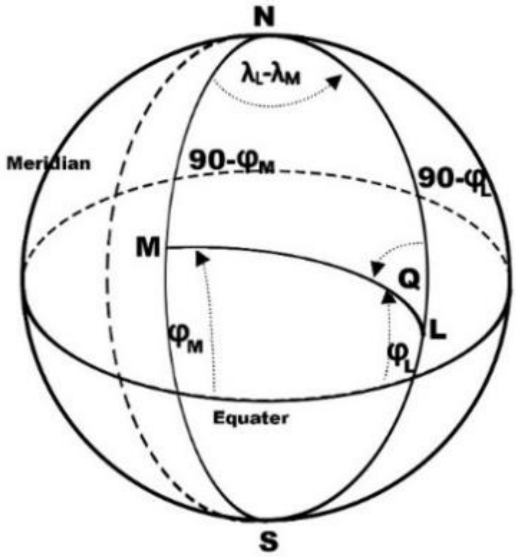



*Figure 2. Spherical Trigonometry Illustration [27]*

$$q = arctan2\left(\frac{sin\,(L - L_M)}{cos(\varphi)\cdot tan(\varphi_M) - sin(\varphi)\cdot cos(L - L_M)}\right), \quad (11)$$

$$arctan2(y,x)\begin{cases} arctan\left(\frac{y}{x}\right) & if\ x > 0 \\ arctan\left(\frac{y}{x}\right) + \pi & \text{if } x < 0\ and\ y \geq 0 \\ arctan\left(\frac{y}{x}\right) - \pi & \text{if } x < 0\ and\ y < 0 \\ +\frac{\pi}{2} & \text{if } x = 0\ and\ y > 0 \\ -\frac{\pi}{2} & \text{if } x = 0\ and\ y < 0 \\ \text{undefined} & \text{if } x = 0\ and\ y = 0 \end{cases} \quad (12)$$

Equation 11 is a mathematical model to determine the azimuth of Qibla by using modern method (spherical trigonometry method). The requirement to obtain the Qibla direction from the North Pole of Earth reference shown in Table 3.

*Table 3. Qibla Direction from the North Pole of Earth Reference of Location Using Modern Method*

| No | Requirement | Qibla Direction |
|---|---|---|
| 1 | $Q > 0$ | $Qibla = 360° - Q$ |
| 2 | $Q < 0$ | $Qibla = -Q$ |

## 3. Experimental Methods

### 3.1 System Design

The system design of this research is divided into two sections. The first section computes the determination of Qibla direction by using ibn al-Haytham's method has been described in Equation 1 – Equation 10. After getting the computation result of the Qibla direction using ibn al-Haytham's method, the result compared with the Qibla direction computation of the modern method (Equation 11).

The second section is implemented ibn al-Haytham's method algorithm to develop the real-time Qibla Direction based Processing 3 (software), Raspberry Pi 4, GPS module, and digital compass. The general system scheme of the Qibla Direction Interface is shown in Figure 3.

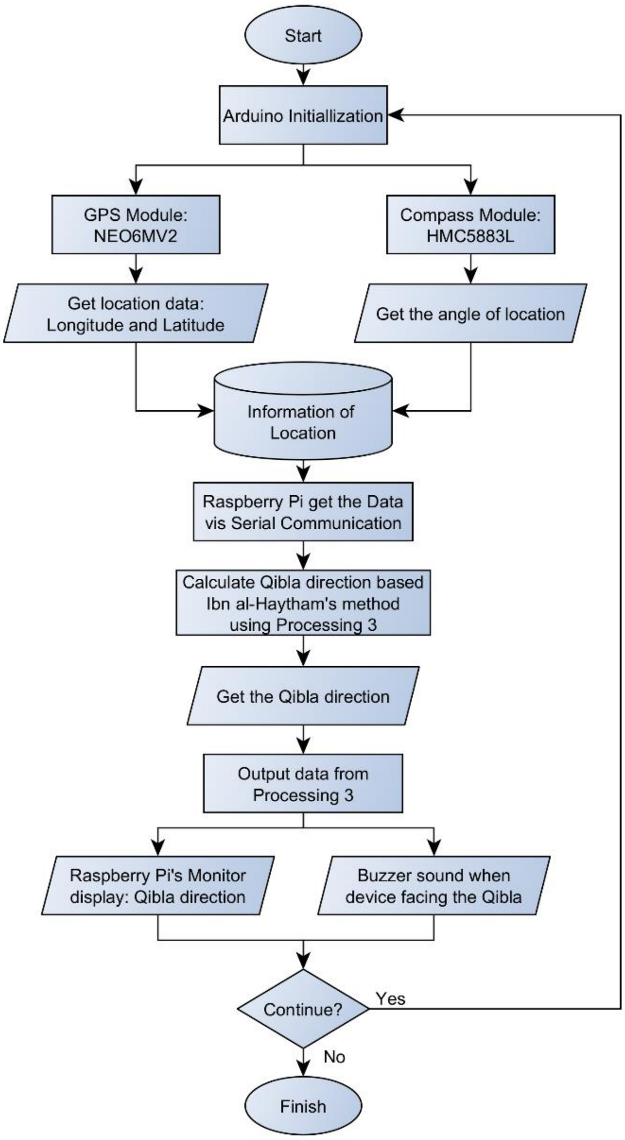
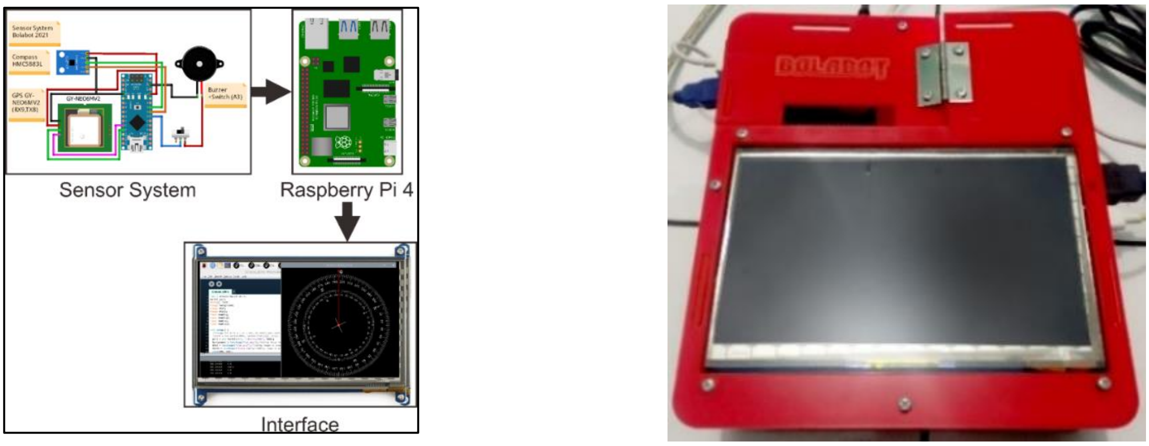



*Figure 3. The General Process of Qibla Direction*

Figure 3 is the Qibla direction system mechanism. The initial process is activating the Arduino board with connected the board to the power supply. Next, the GPS module is active to get the geographical coordinate (latitude and longitude) of a location, and the digital compass gets the direction of a location. Both data are sent by serial communication to Raspberry Pi 4. After that, the coordinate of a location computes using ibn al-Haytham's method for determining Qibla direction. Then the data compute and compare with the digital compass data to get the real direction. Thus, the system can guide users to face the direction of Qibla by looking at the interface in Raspberry Pi's display. In addition, the buzzer/speaker will sound when the system is faces Qibla.

### 3.2 Hardware Design

The circuit system and the realization of the Qibla direction are shown in Figure 4. From the circuit scheme in Figure 4 (a), there are two systems. The first system is the sensor system, there is the Arduino Nano board microcontroller, GPS module (type NEO6MV2) connect to pin 8 (TX) and pin 9 (RX) of Arduino, digital compass connected to pin A5 (SCL) and pin A4 (SDA)of Arduino, and buzzer+switch connected to pin A3 of Arduino (the switch is for activated the buzzer when the buzzer is needed). The second system is the Raspberry Pi as the processor. That system is equipped with a monitor/display to show the interface and guide users to face Qibla direction. The realization of the Qibla direction hardware is shown in Figure 4 (b).




(a) (b)

*Figure 4. Qibla Direction Hardware System: (a) The Circuit Scheme, and (b) The Hardware Realization*

## 4. Results And Discussion

### 4.1 The Computation Results of Qibla Direction Determination

In this section, the numerical computation of ibn al-Haytham's method, and the Modern method to determining Qibla direction is done offline. The numerical computation will test the Qibla direction of some Locations, the locations are; Baghdad, Iraq (Baghdad); Masjid Ikomah UIN Sunan Gunung Djati, Bandung, Indonesia (Bandung); Sudan, Africa (Sudan); and London, UK (London). The geographical coordinate of some Locations is obtained using Google Maps, the data shown in Table 4.

*Table 4. Coordinate of Kaaba and Locations from Google Maps*

| No. | Location | Coordinate of Location | |
|---|---|---|---|
| | | Latitude | Longitude |
| 1 | Kaaba, Mecca | $21°\ 25'\ 21.21''$ N $= 21.422558°$ | $39°\ 49'\ 34.06''$ E $= 39.826128°$ |
| 2 | Baghdad, Iraq | $33°\ 18'\ 54.8''$ N $= 33.315228°$ | $44°\ 21'58.0''$ E $= 44.366118°$ |
| 3 | Masjid Ikomah UIN Sunan Gunung Djati, Bandung, Indonesia | $6°\ 55'\ 53.3''$S $= -6.931484°$ | $107°\ 43'02.6''$ E $= 107.717378°$ |
| 4 | Sudan, Afrika | $16°\ 16'\ 22.2''$N $= 16.272840°$ | $30°\ 19'\ 38.1''$ E $= 30.327236°$ |
| 5 | London, Inggris | $51°\ 30'\ 30.7''$ N $= 51.508530°$ | $0°\ 07'32.7''$ W $= -0.125740°$ |

The computation result of determining Qibla direction by using ibn al-Haytham's method and the Modern method is shown in Table 5.

*Table 5. Qibla direction of Locations using ibn al-Haytham's and modern method from the North Pole of Earth*

| No. | Location | Result | |
|---|---|---|---|
| | | Ibn al-Haytam's Method | Modern Method |
| 1 | Baghdad, Iraq | $199°\ 49'\ 03'' = 199.817563°$ | $199°\ 49'\ 03'' = 199.817563°$ |
| 2 | Masjid Ikomah UIN Sunan Gunung Djati, Bandung, Indonesia | $295°\ 8'\ 46'' = 295.146246°$ | $295°\ 8'\ 46'' = 295.146246°$ |
| 3 | Sudan, Afrika | $58°\ 43'\ 10'' = 58.719484°$ | $58°\ 43'\ 10'' = 58.719484°$ |
| 4 | London, Inggris | $118°\ 59'\ 26'' = 118.990581°$ | $118°\ 59'26'' = 118.990581°$ |

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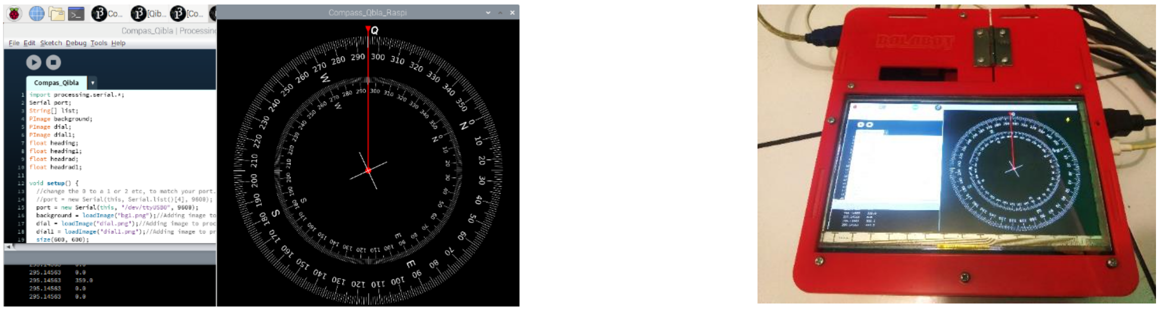
For another test, we compare the Qibla direction result from our previous research using the first of al-Biruni's method [5], the third of al-Biruni's method [4], and modern method [4][5]. The both research test Qibla direction of Ghazna (now: Ghazni, Afghanistan) which have geometrical coordinate $33°\,32'\,49.1''$ N $= 33.543966°$ for latitude and $64°\,25'10.3''$ E $= 68.419711°$ for longitude. From our previous research, all result show the Qibla direction from the North Pole of Earth is $251°\,42'\,41'' = 251.711431°$. After test the Qibla direction of Ghazna using ibn al-Haytam's method, the result show the same value as our previous research is $251°\,42'\,41'' = 251.711431°$ from the North Pole of Earth.

The result from Table 5 and the comparison by our previous research shows that ibn al-Haytham's method is equivalent and has the same accuracy as the modern and al-Biruni's method. It proves that ibn al-Haytham's method is still relevant to use until now, and it can become an alternative method to determining Qibla direction. The numeric calculation steps for determining Qibla direction by using Ibn al-Haytham's method have more than the modern method. However, by using Processing 3 software, the numeric computation result for determining the Qibla direction can get faster and accurate.

### 4.2 The Implementation of Ibn al-Haytham's Method for Determining Qibla Direction

In this section, ibn al-Haytham's method implement to develop Qibla direction device and interface based Raspberry Pi 4, GPS module, digital compass, and Processing 3 software in real-time. To know the Qibla direction from the interface, there is a red arrow as shown in Figure 5. The red arrow shows a direction to faces Qibla direction directly. In addition, there is a buzzer that can be sound when the device faced Qibla. When the buzzer sound is not needed, the sound can be deactivated using a switch.



(a) (b)

*Figure 5. Qibla Direction Testing in Bandung; (a) The Interfac Based Processing 3, and (b) The Device Appearance*

The device is test in a Masjid in Bandung, that is Masjid Ikomah UIN Sunan Gunung Djati using ibn al-Haytham's method and modern method. The testing result is shown in Table 6. The table shows that both methods show the equivalent value and the same accuracy. Then, the device testing result (Table 6) is confirmed with the numerical computation result (Table 5), both data proved to have the same value. Thus, the Qibla direction device and the interface have worked well in real-time.

*Table 6. Real Time Qibla Direction Based on Raspberry Pi Interface from the North Pole of Earth Reference*

| No. | Location | Result | |
|---|---|---|---|
| | | Ibn al-Haytam's Method | Modern Method |
| 1 | Bandung | $295°\,8'\,46'' = 295.146246°$ | $295°\,8'\,46'' = 295.146246°$ |

## 5. Conclusion

The implementation of Ibn al-Haytham's method to determine real-time Qibla direction using Raspberry Pi has been presented. Ibn al-Haytham's numerical method has been computed and compared with the modern spherical trigonometry method and our previous research using al-Biruni's method. The results show that ibn al-Haytham's method has the equivalent and same accuracy as the modern and al-Biruni's method. Then, the algorithm of ibn al-Haytham's method implements to develop Qibla direction device and interface based on Raspberry Pi, GPS module, digital compass, and Processing 3 software in real-time. The result shows that the device can display the Qibla direction interface according to numerical calculations with high accuracy, real-time, and dynamic interface. For future research, we will upgrade the interface to show *Sholat Times*, *local Rashdul Qibla*, and more using another method.

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