THE EFFECT OF MAGNETIC DECLINATION CORRECTION ON SMARTPHONES COMPASS SENSORS IN DETERMINING QIBLA DIRECTION

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Abstract:

Qibla direction applications for smartphones often employ a compass sensor (magnetic orientation) as a reference to identify the directions and detect the qibla direction. The accuracy of the compass sensor in determining the qibla direction is still in doubt, because the compass sensor is easily affected by the surrounding magnetic field, and the north direction indicated by the compass sensor is not true north but the north direction of the Earth's magnetic field. This is surely quite important on the accuracy of the compass sensor in detecting the qibla direction. The north direction given by the compass sensor may be adjusted to true north by applying a magnetic declination adjustment value. This research intends to investigate the influence of magnetic declination correction on the accuracy of the compass sensor on smartphones in calculating the qibla direction. The type of research performed is field research with a quantitative research method. The data were obtained by comparing the qibla direction from the smartphone compass sensor with the qibla direction from the theodolite. This research reveals that the measurement of the qibla direction employs an smartphone compass sensor with a magnetic declination adjustment for the angle difference (deviation) of 03° 55' 0.055" or 437.6815289 kilometers, to the qibla direction from the theodolite.

Keywords: Qibla Direction, Smartphones, Compass Sensor, Magnetic Declination

Abstrak:

Aplikasi arah kiblat pada ponsel android umumnya memanfaatkan sensor kompas (*magnetic orientation*) sebagai acuan untuk menentukan arah mata angin dan mendeteksi arah kiblat. Akurasi sensor kompas dalam menentukan arah kiblat masih diragukan, karena sensor kompas mudah terpengaruh medan magnet di sekitar, dan arah utara yang ditunjukkan oleh sensor kompas bukan arah Utara geografis melainkan arah utara medan magnet Bumi. Hal tersebut tentu sangat berpengaruh pada akurasi sensor kompas dalam menentukan arah kiblat. Arah utara yang dihasilkan oleh sensor kompas dapat dikonversi menjadi arah utara geografis dengan menambahkan nilai koreksi deklinasi magnetik. Penelitian ini bertujuan untuk menganalisis pengaruh koreksi deklinasi magnetik terhadap akurasi sensor kompas pada ponsel android dalam menentukan arah kiblat. Jenis penelitian yang digunakan adalah jenis penelitian lapangan dengan pendekatan kuantitatif. Observasi dilakukan dengan cara membandingkan arah kiblat dari sensor kompas android dengan arah kiblat dari theodolite. Penelitian tersebut menunjukkan bahwa pengukuran arah kiblat menggunakan sensor kompas android dengan koreksi deklinasi magnetik selisih sudut (*deviasi*) sebesar 03° 55' 0,055" atau 437,6815289 km, terhadap arah kiblat dari theodolite.

Kata Kunci : Arah Kiblat, Android, Sensor Kompas, Deklinasi Magnetik

A. Introduction

The qibla direction is one of the crucial things that need to be regarded by Muslims. Most academics agree that one of the prerequisites for a proper prayer is to face the qibla direction. The definition of qibla direction is closest direction to the Kaaba.[1] For Muslims who are around the *Masjidil Haram*, facing the qibla direction is obviously not a difficult problem, because the building Kaaba can be seen directly. Problems will occur, if Muslims are far from the *Masjidil Haram*. Geographically, the position of the Indonesian state is quite far from the site of the *Masjidil Haram*. The condition is very difficult to create confidence whether they are genuinely facing the qibla or not. This is based on the deviation of the qibla direction of one degree, which happens in the

[1] Slamet Hambali, Ilmu Falak 1:*Penentuan Awal Waktu Salat Dan Arah Qiblat Seluruh Dunia* (Semarang: Program Pascasarjana IAIN Walisongo, 2011), 167.

Indonesian region if a straight line is drawn approximately as far as the distance from Indonesia to Mecca, it will suffer a deviation of around 111 kilometers.[2]

Muslims whose position is far from the center of the qibla will undoubtedly have problems facing the qibla properly. Imam Shafi'i gave opinion that there are two ways to face the qibla. The first is *'ainul Ka'bah*, which means facing straight the building Kaaba. This situation is done when we are near or can see directly the building Kaaba. The second is *Jihatul Ka'bah*, which implies that we just have to face the building Kaaba with *zhan* (strong suspicion). This condition is carried out when we cannot see the building Kaaba, or are far from the M*asjidil Haram* area.[3]

Based on the importance of facing the kibla for Muslims, Muslims are advised to make extra effort in *ijtihad* to determine the direction of qibla. *Ijtihad* can be done by calculating the qibla direction, then utilizing the shadow of the Sun or the position of celestial bodies such as the Moon, Planets, and Constellations as a reference in measuring the qibla azimuth.[4] In modern context facing the qibla is not a difficult problem, because there are several methods of determining the qibla direction from classic to contemporary with difference levels of precision. One of modern methode to finding qibla direction is using qibla direction application installed on the smartphones. Finding the qibla direction with using smartphones is easiest and most practical way that can be done by everyone.

Qibla direction applications on a smartphone usually utilize a compass sensor to detect the qibla direction. The compass sensor has a working concept similar to a compass tool in general, so it has several weaknesses, including the compass needle being easily affected by the surrounding magnetic field. The compass needle does not show the true north of the Earth. However, the north

[2] Muhammad Ma'shum, *Durusul Falakiyyah* (Jombang: Maktabah Sa'ad bin Nashir Nabhan wa Awladuhu, 1992), 62.

[3] Abdurrahman bin Muhammad Awwad Al-Jaziry, "1699, Kitabul Fiqh 'Ala Madzahibil Arba'Ah" (Beirut: Dar Ihya'At Turats Al Araby, n.d.), 42.

[4] M Ihtirozun Ni'am, Muhammad Fiki Burhanuddin, and Nizma Nur Rahmi, "Qibla Direction With the Constellation (Study of Determination of Qibla Direction With Gubug Penceng)," Al-Hilal: Journal of Islamic Astronomy 2, no. 2 (2021): 2, https://doi.org/10.21580/al-hilal.2020.2.2.7964.

direction of the Earth's magnetic field.[5] According to Thomas Djamaludin, a compass can be claimed to be an accurate tool in locating true north if you pay attention to two factors. The first item to notice is the metal things around; the second is the magnetic declination value.6 Therefore, it is vital to investigate the functioning system and the level of accuracy of the compass sensor in identifying the qibla direction.

There is various previous research that discusses the qibla direction and magnetic declination. Fathiyatus Sa'adah, in his paper entitled " Pengaruh Deklinasi Magnetic pada Kompas terhadap Penentuan Utara Sejati (True North) di Kota Salatiga." The investigation indicated that the magnetic declination adjustment on the compass affected the determination of true north.[7] Aznur Johan, in his thesis entitled " Aplikasi Perhitungan Arah Qiblat Metode Arah Satu Segitiga Siku-Siku Slamet Hambali pada Smartphone Android," discusses the design of Android application programs by referring to the qibla theory at all times, Slamet Hambali. The data shown in this application are in the form of calculated data which may later be utilized for identifying the qibla direction utilizing the correct triangle method employing a stick as a tool.[8] Scientific journal by Anisa Budiwati with the title " Tongkat Istiwa', Global Positioning System (Gps) dan Google Earth untuk Menentukan Titik Koordinat Bumi dan Aplikasinya dalam Penentuan Arah Qiblat ", Describes the method of determining the coordinates of the Earth with a stick *istiwa'*, GPS, and Google Earth as well as the third application in determining the direction of qibla, in addition, also presented data on the comparison between them so that we can conclude the order of accuracy of each tool.[9] Arino Bemi Sado in his scientific

[5] Wahyudi and M. Didik R, "Rancang Bangun Perangkat Lunak Penentu Arah Qiblat, Penghitung Waktu Shalat Dan Konversi Kalender Hijriah Berbasis Smart Phone Android," *Jurnal Teknik Jurusan Teknik Informatika FST UIN Sunan Kalijaga Yogyakarta* 5, no. 1 (2015): 80.

[6] Tim penyusun Modul, *Ilmu Falak 1 Arah Qiblat dan Aplikasinya* (Semarang: Pondok Pesantren Life Skill Darun Najaah, 2014), 5.

[7] Fathiyatus Sa'adah, "Pengaruh Deklinasi Magnetic pada Kompas terhadap Penentuan Utara Sejati (True North) di Kota Salatiga" (Universitas Negeri Islam Walisongo Semarang, 2013).

[8] Aznur Johan, "Aplikasi Perhitungan Arah Qiblat Metode Arah Satu Segitiga Siku-Siku Slamet Hambali pada Smartphone Android" (Universitas Islam Negeri Walisogo Semarang, 2014).

[9] Anisah Budiwati, "Tongkat Istiwa', Global Positioning System (Gps) dan Google Earth untuk Menentukan Titik Koordinat Bumi dan Aplikasinya dalam Penentuan Arah Qiblat," *Al-Ahkam* 26, no. 1 (2016): 65, doi:10.21580/ahkam.2016.26.1.808.

journal entitled " Pengaruh Deklinasi Magnetik pada Kompas dan Koordinat Geografis Bumi terhadap Akurasi Arah Qiblat ", explains that the magnetic declination of the compass and the geographical coordinates of the earth have a considerable influence on the accuracy of the qibla direction. In addition, no interactive relationship was found between the magnetic declination and the geographical coordinates of the earth, which from this interaction will affect the correctness of the qibla direction.[10]

Based on various previous research related to magnetic declination and qibla direction, the authors intended to analyze the influence of magnetic declination correction on the smartphones' compass sensor's accuracy in detecting the qibla direction. This study aims to determine the level of accuracy of the compass sensor in identifying the qibla direction so that we can utilize it for consideration as a means of calculating the qibla direction.

B. Method

This research is included in field research where the author makes observations by comparing the results of measuring the qibla direction from the compass sensor with the qibla direction from the theodolite. The author chose theodolite as an instrument with great precision in measuring the qibla direction. Observations were also conducted five times in various locations and at different times. Furthermore, the gathered data be analyzed using a quantitative numerical technique.

Prior to conducting observations, the author created a qibla direction application on smartphones using the compass sensor. This application's qibla direction calculation formula is based on the qibla direction formula from Slamet Hambali's book "Ilmu Falak 1." The magnetic declination has been used to adjust the qibla direction in this application automatically. The magnetic declination value in this application was obtained from the website

[10] Arino Bemi Sado, “Pengaruh Deklinasi Magnetik Pada Kompas dan Koordinat Geografis Bumi terhadap Akurasi Arah Qiblat,” *AL-AFAQ: Jurnal Ilmu Falak Dan Astronomi* 1, no. 1 (2019): 1–12.

www.ngdc.noaa.gov.[11] This application will be used to see how magnetic declination correction affects the smartphone compass sensor's ability to determine the qibla direction.

C. Discussion and Results

C.1. Qibla Direction Deviation Limit

For Muslims who live far from the position of the Kaaba, a tolerance limit for deviations in facing the qibla is required. Tolerance in facing the qibla direction attempts to give convenience and flexibility when performing prayer or other religious ceremonies in facing the qibla direction. According to Zainul Arifin, tolerance is the measurement value's limit for adding or subtracting a value within the level that is still permitted or a variance that is still acceptable..[12]

The tolerance for deviations from the qibla direction varies depending on the viewpoint of each fiqh expert. According to certain fiqh experts, tolerance for qibla direction is transmitted with a hint, while others express it with a precise value. Sheikh Mohammad Yasin said in his book " *Syarah Ṡamarāt al-Wasīlah*" that tolerance towards the qibla for locations far distant from the city of Mecca is separated into two *al-jihah al-kubro* and *al-jihah al-sugro*. *Jihah kubro* is the 180° angle between the East and West or South and North orientations towards the qibla. While the definition of *jihah Sugro* faces the qibla for an arc of 90°, it indicates we are facing the qibla with the greatest allowable deviation to the left 45° or right 45°.[13]

Another point of view was expressed by Ma'rufin Sudibyo, who proposed a concept of tolerance towards the direction of the qibla known

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[11] On the webpage, the magnetic declination value is taken from the World Magnetic Model (WMM), which was collaboratively produced by the National Centers for Environmental Information (NCEI) and the British Geological Survey (BGS).

[12] Zainul Arifin, "Toleransi Penyimpangan Pengukuran Arah Qiblat," *Elfalaky Jurnal Ilmu Falak* 2, no. 1 (2018): 62–75.

[13] Siti Nurul Ifah Faridah, "Toleransi Arah Qiblat Menurut Mazhab Hanafi dalam Prespektif Fikih dan Astronomi" (Universitas Islam Negeri Walisongo Semarang, 2017), 5.

as *ihtiyathul qiblat*. In this idea, the tolerance value corresponds to a variation of 45 kilometers as the distance between the Kaaba and the coordinates of the junction of the Quba Mosque. The Quba mosque's history was the first mosque erected directly by the prophet Muhammad SAW in 612 AD. According to satellite photographs, the Quba mosque is rectangular and is located at coordinates 24°26' N 39°37' E. Observation findings using Google Earth software show that the Quba Mosque has a qibla azimuth value of 176°28' however the qibla direction of the mosque does not face the value of azimuth 176°28', but instead leads to an azimuth of 184° 06', resulting in an angle of deviation of 7° 38'. Quba Mosque is located 45 kilometers west of Mecca. Similar measurements were taken on the qibla direction of the Nabawi Mosque, which revealed that the Nabawi Mosque likewise experienced a departure from the qibla direction, but at a lower amount than the Quba Mosque.[14]

In this study, the author uses Ma'rufin Sudibyo's opinion as a guideline for the tolerance limit for deviations from the qibla direction. The tolerance limit for deviation of the qibla direction, according to Ma'rufin Sudibyo, is 45 kilometers. If the study's results show that the compass sensor's qibla direction has a deviation of fewer than 45 km, it can be concluded that the compass sensor has high accuracy in determining the qibla direction. However, if the qibla direction deviation exceeds 45 kilometers, the qibla direction estimation using the compass sensor is inaccurate.

C.2. Instrument for Measuring Qibla Direction

The advancement of science and technology affects the advancement of astronomy. This is shown by the numerous improvements made by moslem astronomers in the subject of rukyat reckoning, one of which is innovation in instrumentation or measuring devices used to

[14] Muh Sudibyo, "Sang Nabipun Berputar: Arah Qiblat dan Tata Cara Pengukurannya," *Solo: Tinta Media*, 2011, 7.

determine the direction of qibla. The following equipment can be used to assist determine the qibla direction:

1) *Segitiga Qiblat*

   This instrument determines the qibla direction by forming a right triangle from the value of the qibla direction angle of a location. Before we can use the *segitiga qiblat*, we must first determine the qibla azimuth and true north. The calculating idea employed in the *segitiga qiblat* is trigonometry, which involves knowing one of the triangle's side lengths and then drawing the qibla line from both ends of the side whose value is known..[15]

2) *Rubu' Mujayyab*

   This tool is an astronomical instrument used in the Middle Ages that functions to solve difficulties in the field of Spherical Astronomy. *Rubu' mujayyab* in astronomy is used as a tool to determine the data needed for a reckoning at the beginning of prayer times and also the direction of the qibla.

3) *Tongkat Istiwa'*

   It simply requires an instrument or a perpendicular stick, which can be built of wood, iron, or other objects, to determine the qibla direction. In an upright position, the stick is positioned right in the center or center point of the circle. The qibla direction can be determined by first locating the focal point based on the shadow of the stick and the azimuth value of the Sun and then drawing a correct East-West line. After knowing the accurate cardinal directions, the qibla direction can be measured according to the calculation results of the qibla azimuth of the place.[16]

4) Compass

[15] Ahmad Izzuddin, *Ilmu Falak Praktis*, 1st ed. (Jakarta: Kementerian Agama RI, 2013), 69.

[16] Ahmad Izzuddin, *Kajian Terhadap Metode-Metode Penentuan Arah Qiblat dan Akurasinya* (Jakarta: Kementerian Agama RI, Direktorat Jenderal Pendidikan Islam, 2012), 146–47.

A compass is an instrument used to determine the cardinal directions.[17] The compass needles are constructed of magnetic metal and are fixed so that they readily rotate to point to the north. It's only that the north direction displayed is not true north (the point of the north pole), but rather the magnetic north of the earth, whose location is constantly changing and does not correlate with the earth's poles. To get true north, the compass declination must be corrected to the direction of the compass needle.[18]

5) Mizwala Qibla Finder

   Mizwala is a qibla -determining instrument that consists of a gnomon or little stick and a circular dial. This instrument uses the sun's shadow to determine the qibla direction. The azimuth value of the sun at a specified moment is required before measuring the qibla direction; after the genuine cardinal directions are known, the thread on the dial can be adjusted by the qibla azimuth value.[19]

6) *Istiwa'aini*

   Istiwaaini is *tatsniyyah* of the term *istiwa'*, which means "*two sticks istiwa'*." It comprises two gnomons (small sticks) and a circular dial. The first stick is at the middle of the circle, while the second stick is at 0° on the circle's rim. Using the sun's shadow, this tool determines the true north and the qibla direction.[20]

7) Theodolite

   Theodolite is a geological and geodetic instrument used for mapping to measure vertical and horizontal angles with a high degree of precision. This tool may also be used as a rukyat tool to determine the altitude and azimuth of celestial bodies, as well as the qibla direction.[21]

8) Compass Sensor

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[17] Susiknan Azhari, *Ensiklopedi Hisab Rukyat*, 2nd ed. (Yogyakarta: Pustaka Pelajar, 2008), 125.

[18] Muhyiddin Khozin, "Ilmu Falak dalam Teori dan Praktik" (Yogyakarta: Buana Pustaka, 1996), 31.

[19] Izzuddin, *Kajian Terhadap Metode-Metode Penentuan Arah Qiblat dan Akurasinya*, 83.

[20] Slamet Hambali, *Menguji Tingkat Keakuratan :Hasil Pengukuran Arah Qiblat Menggunakan Istiwaaini Slamet Hambali* (Semarang: LP2M, 2014), 56.

[21] A Kadir, *Cara Sederhana Menentukan Arah Salat Agar Sesuai Syari'at. Yogyakarta*, 1st ed., 2012, 43.

The compass sensor is a type of electrical direction sensor that determines the direction of the north. This sensor's operating mechanism is similar to that of a compass in that it detects the horizontal direction of the earth's magnetic field, which is then processed so that it may be represented digitally.[22] This sensor's capability may be utilized to create robots or software that identify the qibla direction.

C.3. Compass Sensor (Magnetic Orientation)

Wilhelm von Siemens introduced sensor technology in 1860, according to history. He built a temperature measuring apparatus out of copper wire using a functioning method based on a resistor. Sensor technology was first utilized in the industrial sector as a measuring instrument to detect a parameter that can function automatically and correctly, hence increasing production outcomes. The large-scale expansion of the industrial sector from 1920 to 1940 resulted in an increased need for automation technologies: sensor technology. Because semiconductor technology can process electrical signals and control procedures more quickly, its introduction in 1950 prompted the fast growth of sensor technology.[23] Sensor technology evolves, giving a variety of advanced functions and components to aid human work.

A sensor is a component of an electronic measuring system that may collect an input signal in the form of a parameter or a quantity and convert it into a signal or other quantity that can then be displayed, recorded, or utilized as a feed signal in the control system. Sensors, in general, may transform a received parameter into an electrical signal. Sensors, also known as detectors, are converters that can measure physical

[22] Rusgianto, "Kompas Magnetik Digital dengan Keluaran Suara Berbasis Mikrokontroler AT89S51," *Jurnal Fisika FLUX* 8, no. 2 (2011): 7.

[23] T Grandke, *Sensors a Comprehensive Survey : Fundamentals and General Aspects* (New York: VCH Publishers Inc, 1989), 2.

quantities and turn them into signals that observers or electronic equipment can interpret.[24]

According to Rafiuddin Syam, a sensor is a detecting device for measuring a physical quantity such as pressure or light. The sensor will then convert the measurement data into a signal that people can interpret. Currently, most sensor technologies can interface with electronic equipment, making measurement and recording easier.[25] The American National Standards Institute (ANSI) defines a sensor as a device that generates usable output in response to a defined measuring quantity. The output referred to in this definition is an electrical quantity, even though a measuring quantity is a physical quantity arising from a parameter measurement process.[26]

Smartphones are rapidly increasing in popularity. This is characterized by innovations capable of facilitating all human activities. One of the advancements that make Smartphones more sophisticated is the inclusion of sensors such as accelerometers, gyroscopes, magnetometers, barometers, humidity, pressure, light, proximity, and heart rate monitors. The compass sensor or magnetic orientation is one of the sensors in Smartphones that can assist human activities. This sensor determines the mobile device's position, which can be used for Google Maps navigation applications, augmented reality games, and even qibla direction apps. On Smartphones, the compass sensor is a hybrid of two sensors: an accelerometer and a geomagnetic sensor.[27]

The accelerometer sensor is a sensor that can measure acceleration or calculate changes in acceleration based on an object's location. This sensor in Smartphones detects changes in the orientation of the screen tilt

[24] Jogiyanto Hartono, *Pengenalan Komputer: Dasar Ilmu Komputer, Pemrograman, Sistem Informasi dan Inteligensi Buatan* (Yogyakarta: AndiPublisher, 2005), 89.

[25] Rafifuddin Syam, *Dasar-Dasar Teknik Sensor* (Makassar: Fakultas Teknik Universitas Hasanuddin, 2013), 9.

[26] Grandke, *Sensors a Comprehensive Survey : Fundamentals and General Aspects*, 3.

[27] "Guides Sensor Position" https://developer.android.com/guide/topics/sensors/sensors_position, accessed on March 20, 2020 at 02.12 Local Time.

and rotates the phone screen in landscape and portrait modes. When we tilt or straighten the phone, it will automatically rotate.

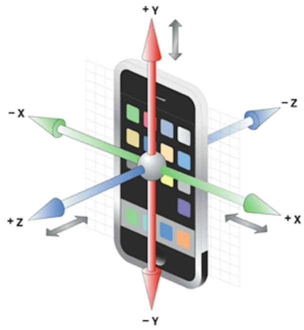

Figure 1 : Accelerometer Sensor working system [28]

Geomagnetic sensors in smartphones employ cutting-edge solid-state technology to create microscopic hall-effect sensors capable of detecting the earth's magnetic field along the X, Y, and Z axes. The sensor ax shall-effect generates a voltage proportionate to the intensity and polarity of the field magnet along each sensor's axis. The received voltage will then be translated into a digital signal that indicates the magnetic field intensity. The magnetometer sensor detects a magnetic field with one microTesla unit (μT) magnitude. When experimenting with this sensor, the effect of rotating the feature relative to magnetic north or bringing a magnet closer to the sensor may be seen.[29]

[28]https://developer.apple.com/library/archive/documentation/UserExperience/Conceptual/DesigningExpandedAdUnits/FeaturesforExpandedAdUnits/FeaturesforExpandedAdUnits.html, accessed on 10 June 2021 at 11.12 Local Time.

[29] Dinar Winia Mahandhira, "Penggunaan Accelerometer dan Magnetometer pada Sistem Real Time Tracking Indoor Position untuk Studi Kasus pada Gedung Teknik Informatika ITS," *JURNAL TEKNIK ITS* 5, no. 2 (2016): 8.

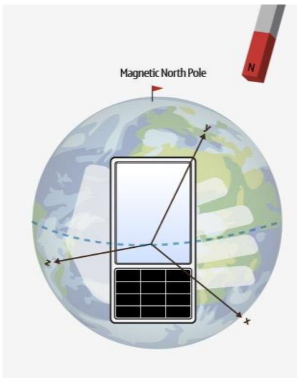

Figure 2: Geomagnetic Sensor working system [30]

The functioning system of the compass sensor is identical to that of a compass tool in general. The compass sensor will detect the Earth's magnetic field horizontally as a reference point in identifying the cardinal directions. It should be noted that the cardinal directions provided by the compass sensor are not geographic cardinal directions but rather magnetic field poles. The most accurate way to determine the qibla direction is to utilize a true north reference point. The north direction generated by the compass sensor must be adjusted for magnetic declination to improve accuracy. Magnetic declination is the angular difference between the true north and the magnetic poles of the Earth.

C.4. Magnetic Declination

Earth is a place of life for all creatures on the globe has a magnetic field that spans its whole surface along the North and South poles. The earth's magnetic north pole is near the earth's south pole, whereas the earth's magnetic south pole is near the earth's north pole. This earth magnet may be utilized as an alternative to the cardinal directions that we can determine while using a compass. The needle on the compass will always spin, following the position of the earth's magnetic poles. The wrong location of the earth's magnetic poles is at the actual earth's poles, leading the cardinal directions shown by the compass to have a different

[30] https://doc.qt.io/qt-5/qmagnetometerreading.html, diakses pada 10 Juni 2021 pada pukul 11.30 WIB

angle from the accurate cardinal directions. The difference in angle is termed the magnetic declination. Earth's magnetic field is represented as curving lines emanating from the earth's south pole towards the earth's north pole. This earth's magnetic deviation will form lines of earth's magnetic force that vary from the true north-south direction.[31]

Magnetic declination is the angle between true north and magnetic north that occurs from the compass deviation from true north. The value of magnetic declination in each location of the globe has a value that varies. The variation is also time-dependent; therefore, the date for calculating the magnetic declination shows on the map. The date of determination of the declination reveals a yearly change in the magnetic poles. The magnetic declination at a particular point is the angle between the north direction of the compass needle and the true north pole. This term applies to all parts of the globe, including the southern hemisphere. The magnetic declination at a location may be described as the angle between locating the north of the compass needle and the north indication of the site's longitude. If the north of the compass points to the west or the left of the longitude, it has a declination direction of W (west), and if it points east or to the right of the longitude, it has a declination direction of E (east).[32]

Magnetic declination changes from year to year. It is caused by the movement of the Earth's magnetic field. There are various techniques for obtaining the magnetic declination value for a certain point, including: [33]

a. Declination Charts

Most high-quality topographic maps feature diagrams indicating the magnetic declination for the region represented by the map. This graphic is known as a declination diagram. Usually, the

[31] Agung Mulyo, *Pengantar Ilmu Kebumian* (Bandung: Pustaka Setia, 2008), 76.

[32] Fred Touche, *Wilderness Navigation* (Canada: Friesens Corporation, 2005), 50.

[33] Sa'adah, "Pengaruh Deklinasi Magnetic pada Kompas Terhadap Penentuan Utara Sejati (True North) di Kota Salatiga," 38.

date and the yearly rate of change when the declination was measured are also mentioned. The longer the declination date, the less accurate the declination reported will be and the yearly change.

To perform a declination adjustment, it is crucial to know how many degrees the declination number is and whether the declination is east or west from the zero declination line. This magnetic declination information may be retrieved by glancing at the declination diagram at the edge of the topographic map. An arrow with a starred tip denotes true north, whereas MN symbolizes magnetic north. If the MN arrow is to the east of the true north arrow, then the declination in that location is east. On the other side, in regions with a west declination, the MN arrow will be to the left of the true north arrow. The declination value is inscribed in degrees on the side of the arrow. If the map does not contain a declination diagram, the information is generally put on the edge of the map.

b. Compass rose

Sailors in navigation typically utilize a compass rose rather than a declination chart. Compass rose consists of two circles. First is the inside, which is a magnetic bearing. Second, the outside, which covers the inside. In terminology marine, declination is termed variation. In the compass rose, the difference between the bearing on the inner circle and the bearing on the outer ring. As a complement, variations, both the date and the yearly rate of change, are frequently inscribed on the inside of the circle.

c. Computer Software and Website

To determine the magnetic declination value, you may use software magnetic declination calculators such as the WMM (World Magnetic Model) and IGRF (International Geomagnetic Reference Field). WMM is a standard for navigation commonly used in the United States and the United Kingdom. While IGRF is commonly employed in the area of research. (WMM) forecasts the magnetic declination for a given latitude and longitude on a particular date. The Defense Mapping Agencies (DMA) released a variety of WMM models. This model is updated every 5 years by the National Geophysical Data Center (NGDC) in partnership with the British Geological Survey (BGS). These models are based on geomagnetic survey observations from airplanes. Satellites and geomagnetic observatories.

C.5. Aplication Design

Design is carried out since the author has not discovered an android qibla compass application equipped with magnetic declination adjustment. In addition, by developing the application itself, the author may find out the formula for calculating the qibla direction and the magnetic declination data utilized in the program in detail. The application is created using the programming *Javalanguage*[34]. he first step is to construct a command to obtain the coordinates of a location by using the Smartphone GPS function.

```
//deklarasi penggunan GPS
locationManager = (LocationManager) getSystemService(Context.LOCATION_SERVICE);
if (ActivityCompat.checkSelfPermission(this, Manifest.permission.ACCESS_FINE_LOCATION)
!= PackageManager.PERMISSION_GRANTED && ActivityCompat.checkSelfPermission
(this, Manifest.permission.ACCESS_COARSE_LOCATION)
!= PackageManager.PERMISSION_GRANTED) {
    return;
}
locationManager.requestLocationUpdates(LocationManager.GPS_PROVIDER, 0, 0, this);

@Override
public void onLocationChanged(Location location) {

    //mendapat nilai kordinat
    lt=location.getLatitude();
    bt=location.getLongitude();
```

Figure 3: Coding of GPS activation and retrieval of location coordinates

The second step is taking the magnetic declination value. The magnetic declination value utilized is taken from the World Magnetic Model (WMM), which the National Centers for Environmental Information collaboratively created (NCEI) and the British Geological Survey (BGS).[35] The

[34] Java is a programming language that can be executed on various computers including mobile phones. This language was initially invented by James Gosling while still at Sun Microsystems, currently part of Oracle and released in 1995.

[35] NCEI and BGS are institutes that are authorized to undertake research on geophysical conditions, one of which is research on the earth's magnetism.

database is accessed via the website *www.ngdc.noaa.gov*, which is a public domain or free to use for the public.

Figure 4: NOAA website interface

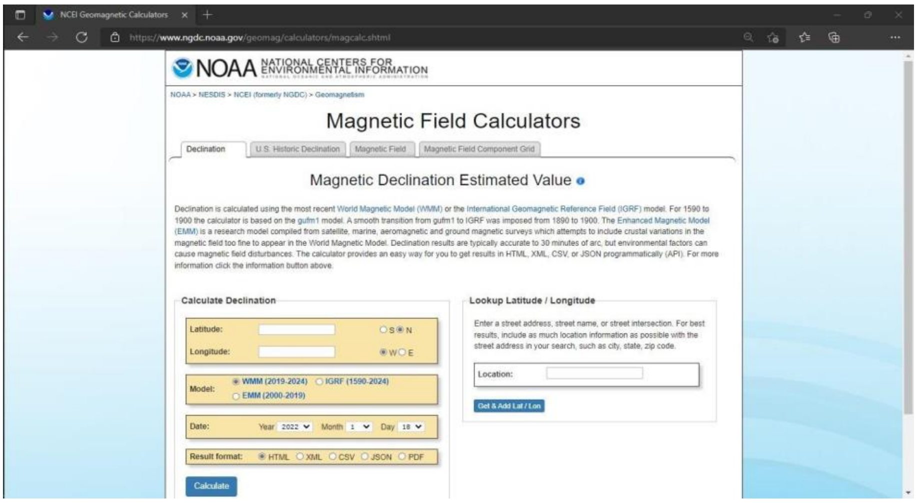

Figure 5: NOAA webpage magnetic declination calculator

```
//memanggil class TSAGeoMag
    TSAGeoMag magModel = new TSAGeoMag();
//save deklinasi magnetic
        double dm = magModel.getDeclination(lt, bt, desimalkalender, 0);
        mEditor.putString(getString(R.string.deklinasi_magnetic), String.valueOf(dm));
        mEditor.commit();
```

Figure 6: Coding to obtain magnetic declination

The third step is to compute the qibla azimuth value. The steps to determine the qibla azimuth are as follows:

1) Determine the value of C, which is the difference between the longitude of the Kaaba and the longitude of the location. To obtain the value of C, you may utilize the following conditions:[36]
2) If BTx > BTk, then C = BTx – BTk. That is, if the east longitude of the city X is larger than the east longitude of the Kaaba, then to obtain C it is known by the formula of the East Longitude of the City X - the East Longitude of the Kaaba (East Longitude of the Kaaba is 39° 49' 34.33";
3) If BTk > BTx , then C = BTk – BTx. For example, if the east longitude of the Kaaba is larger than the east longitude of the city X, then to obtain C it is known by the formula East Longitude of the Kaaba – East Longitude of City X;
4) If BBx is between 0° to 140° 10' 25, 67 "(antipode longitude of the Kaaba), then C = BBx + BTk. This indicates that if city X is located on the west longitude from 0° to 140° west longitude 10' 25.67", then C is the west longitude of the city X + East longitude Kaaba; and
5) If BBx is between 140° 10' 25.67" to 180°, then C = 360° – BBx – BTk . The argument is that if city X is located between west longitude 140° 10' 25.67" and 180° west longitude, then C is 360° - West longitude of city X - East longitude of the Kaaba.

The coding to calculate the value of C (the difference between the longitude of the Kaaba and the longitude of the place) is as follows:

```
//perhitungan arah kiblat
double lk=21.42251111;//lintang ka'bah
double bk=39.82620278;//bujur ka'bah

//mencari C (selisih bujur ka'bah dengan daerah)
double c = 0;
String arah="barat";
if (bt >=0 && bt>bk){
    c=bt-bk;
    arah="barat";
}else if (bt>=0 && bt<bk){
    c=bk-bt;
    arah="timur";
}else if (bt<0 && bt <140.1722222){
    c=bt+bk;
    arah="timur";
}else if (bt<0 && bt > 140.172222){
    c=360-bt-bk;
    arah="barat";
}
```

[36] Slamet Hambali, *Ilmu Falak Arah Qiblat Setiap Saat* (Yogyakarta: Pustaka Ilmu, 2013), 18.

Figure 7 : Coding to calculate the value of C (difference between the longitude of the Kaaba and the longitude of the location)

6) After calculating the value of C, then calculate the qibla direction. To determine formulae qibla direction using the following formula:[37]

$$\textbf{Cotan } B = \tan \varphi k \cos \varphi x : \sin C - \sin \varphi x : \tan C$$

Description:

B	:	Qibla is calculated from points north or south, if the calculation of the positive direction of qibla is calculated from the point North, and if the calculation result is negative, it is calculated from the South point. B may be termed the qibla direction arc or the qibla direction angle
Φk	:	is a Kaaba latitude is 21 ° 25 '20.98 "N
Φx	:	is the local latitude will be counted towards qibla
C	:	is the shortest longitude from the Kaaba to the East or West to the longitude of the location where the qibla direction will be measured

```
//perhitungan arah kiblat
double tanlk=   Math.tan(lk*Math.PI/180);
double coslt=   Math.cos(lt*Math.PI/180);
double sinc=    Math.sin(c*Math.PI/180);
double sinlt=   Math.sin(lt*Math.PI/180);
double tanc=    Math.tan(c*Math.PI/180);

//rumusarahkiblat
double kiblat=Math.toDegrees(Math.atan(1/((tanlk*coslt/sinc)-sinlt/tanc)));
```

Figure 8 : Qibla direction calculation coding

7) Azimuth can be obtained from the results of the qibla direction calculation (B) using the following conditions:[38]
   a) If B (qibla direction) = UT, then the qibla azimuth is fixed.
   b) If B (qibla direction) = ST, then the qibla azimuth is 180° + B.
   c) If B (qibla direction) = SB, then the qibla azimuth is 180° – B.

---

[37] Hambali, *Ilmu Falak 1:Penentuan Awal Waktu Salat dan Arah Qiblat Seluruh Dunia*, 18.
[38] Slamet Hambali, *Ilmu Falak* (Semarang: UIN Walisongo, 2018), 22–23.

d) If B (qibla direction) = UB, then the qibla azimuth is 360 ° – B.

```
//mencari azimut kiblat
if (kiblat>=0 && arah=="timur"){
    azkiblt=kiblat;
}else if (kiblat>=0 && arah=="barat") {
    azkiblt = 360 - kiblat;

}else if (kiblat<0 && arah=="timur"){
    azkiblt=180-Math.abs(kiblat);

}else if (kiblat<0 && arah=="barat"){
    azkiblt=180+Math.abs(kiblat);
}
```

Figure 9 : Qibla azimuth calculation coding

The fourth step is to generate an access command on the compass sensor, which will later be utilized to identify the qibla direction. By default, the compass sensor will indicate the direction of the earth's magnetic north. To change the reference point by default, the compass sensor to the qibla direction is to utilize the method:

Qibla Direction = Sensor default value – qibla azimuth value – Magnetic declination value

```
// get the angle around the z-axis rotated
degreekiblat = Math.round(event.values[0])-(float)azkiblt-dm;

// create a rotation animation (reverse turn degree degrees)kiblat
RotateAnimation rakiblat = new RotateAnimation(
        currentDegreekiblat,
        -degreekiblat,
        Animation.RELATIVE_TO_SELF, 0.5f,
        Animation.RELATIVE_TO_SELF,
        0.5f);

// Start the animation Kiblat
Kiblat.startAnimation(rakiblat);
currentDegreekiblat = -degreekiblat;
// how long the animation will take place
rakiblat.setDuration(210);
// set the animation after the end of the reservation status
rakiblat.setFillAfter(true);
```

Figure 10: Coding the implementation of the qibla azimuth and magnetic declination values into the android compass sensor

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Figure 11 : Application display

C.6. Test Accuracy

So far, the theodolite is considered the most accurate tool among numerous different qibla direction measuring instruments..[39] The very high degree of precision is why researchers utilize theodolite as a sensor accuracy compass. Sensor application qibla direction test accuracy The compass with theodolite was carried out five times at various locations and times using a different smartphone. As for the results of the study:

1) The first accuracy test was conducted at the mosque campus 3 UIN Walisongo Semarang on Thursday 26 June 2018 at 10:17 Local Time.

Data	Value
Latitude	- 6° 59' 31.58"
Longitude	110° 21' 1.99"
Qibla Azimuth	294° 31' 6.35"
Sun Azimuth	33° 34' 25"
Magnetic Declination	0.79651
Smartphone	Sony Xperia XZ1

[39] Ahmad Izzuddin, *Menentukan Arah Qiblat Praktis*, 1st ed. (Yogyakarta: Logung Pustaka, 2010), 55.

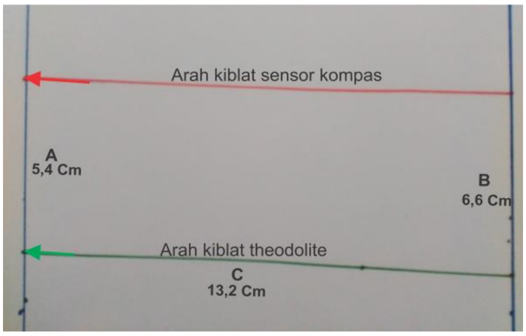

Figure 12 : First accuracy test results

Based on the initial accuracy test, the qibla direction indicated by the compass sensor and theodolite has an angle difference of 05° 11' 0.040". The value of the angle difference can be calculated using the following trigonometric formula:

Angle difference	:	Atan (B – A) / C
	:	Atan (6.6 - 5.4) / 13.2
	:	**5.194428908** (05° 11' 0.040".)

2) The second accuracy test was carried out in the courtyard of the Masjid Agung Jawa Tengah (MAJT) on Thursday 26 June 2018, at 15: 15 Local Time.

Data	Value
Latitude	- 6° 59' 2.07”
Longitude	110° 26' 44.3”
Qibla Azimuth	294° 29' 38.97”
Sun Azimuth	301° 55' 50”
Magnetic Declination	0.799953
Smartphone	Sony Xperia XZ1

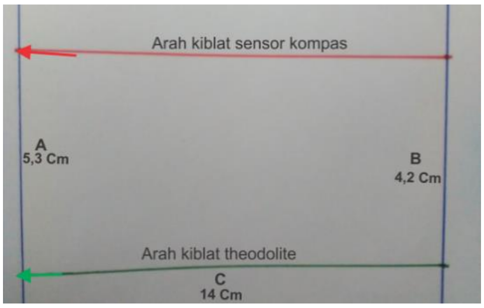

Figure 13 : Second accuracy test results

Based on the second accuracy test, the qibla direction shown by the compass sensor and theodolite yields an angle difference of 04° 29' 0.033". The value of the angle difference can be calculated using the following trigonometric formula:

Angle difference	:	Atan (A – B) / C
	:	Atan (5.3 - 4.2) / 14
	:	**4.492581** (04° 29' 0.033")

3) The third accuracy test was carried out in the mosque on campus 3 of UIN Walisongo Semarang on Friday 27 June 2018 at 09:26 Local Time.

Data	Value
Latitude	- 6° 59' 31.58”
Longitude	110° 21' 1.99”
Qibla Azimuth	294° 31' 6.35”
Sun Azimuth	46° 30' 39”
Magnetic Declination	0.796395
Smartphone	Xiaomi Redmi 6 Pro

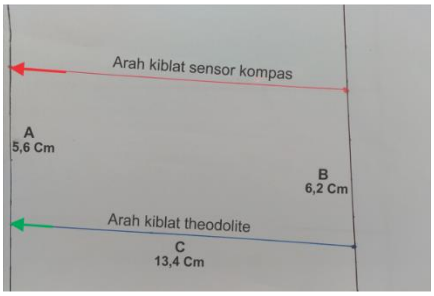

Figure 14 : Third accuracy test results

Based on the third accuracy test, the qibla direction shown by the compass sensor and theodolite yields an angle difference of 02° 33' 0.050". The value of the angle difference can be calculated using the following trigonometric formula:

Angle difference	:	Atan (B – A) / C
	:	Atan (6.2 - 5.6) / 13.4
	:	**2.56377** (02° 33' 0.050")

4) The fourth accuracy test was carried out in the Masjid Agung Jawa Tengah (MAJT) courtyard on Friday, 27 June 2018, at 15: 49 Local Time.

Data	Value
Latitude	- 6° 59' 2.07”
Longitude	110° 26' 44.3”
Qibla Azimuth	294° 30' 54.33”
Sun Azimuth	298° 47' 31”
Magnetic Declination	0.799836
Smartphone	Xiaomi Redmi 6 Pro

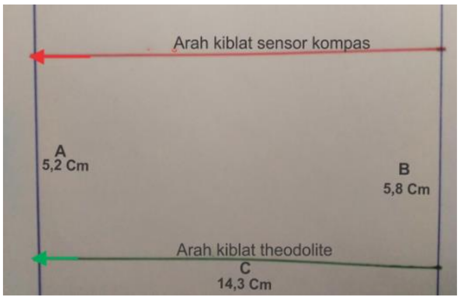

Figure 15 : Fourth accuracy test results

Based on the fourth accuracy test, the qibla direction shown by the compass sensor and theodolite yields an angle difference of 02° 24' 0.009". The value of the angle difference can be calculated using the following trigonometric formula:

Angle difference	:	Atan (B – A) / C
	:	Atan (5.8-5.2) / 14.3
	:	**2.402609** (02° 24' 0.009")

5) The fifth accuracy test was carried out in the campus mosque of UIN Walisongo Semarang on Saturday, June 28, 2018, at 09:35 Local Time.

Data	Value
Latitude	- 6° 59' 13.35"
Longitude	110° 21' 33.9"
Qibla Azimuth	294° 30' 54.33"
Sun Azimuth	44° 42' 42"
Magnetic Declination	0.796721
Smartphones	Sony Xperia XZ1

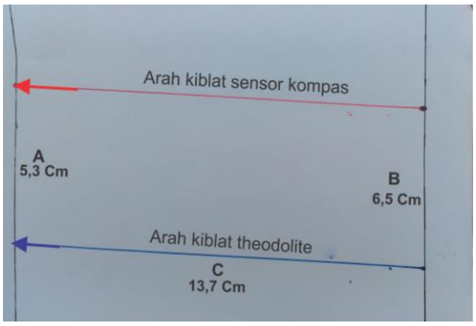

Figure 16 : Fifth accuracy test results

6) Based on the fifth accuracy test, the qibla direction indicated by the compass sensor and theodolite yields an angle difference of 05° 00' 0.021". The value of the angle difference can be calculated using the following trigonometric formula:

Angle difference : Atan (B – A) / C

: Atan (6.5-5.3) / 13.7

: **5.005833** (05° 00' 0.021")

C.7. Data analysis

The results of measuring the qibla direction using the compass sensor of the smartphone obtained the difference in the angle with the qibla direction from the theodolite. The following is the angle difference data from the accuracy-test with the theodolite:

No	Place	Smartphone	Angle difference
1	Campus mosque 3 UIN Walisongo	Sony Xperia XZ1	05° 11' 0.040"
2	Masjid Agung Jawa Tengah	Sony Xperia XZ1	04° 29' 0.033"
3	Campus mosque 3 UIN Walisongo	Xiaomi Redmi 6 Pro	02° 33' 0.050"
4	Masjid Agung Jawa Tengah	Xiaomi Redmi 6 Pro	02° 24' 0.009"
5	Campus mosque 1 UIN Walisongo	Sony Xperia XZ1	05° 00' 0.021"
	Total angle difference		**19° 39' 0.033 "**

The accuracy test was conducted five times, giving a distinct angle difference. The accuracy test carried out using the Sony Xperia XZ1 smartphone had an angle discrepancy in the range of 04° - 05°, whereas the accuracy-test has done with the Xiaomi Redmi 6 Pro Smartphones resulted in an angle difference of just 02°. This indicates that the compass sensor built-in each brand and model of Smartphones has varied specs and capabilities. Based on the table above, it can be calculated the average value of the difference in the angle between the qibla direction of the compass sensor and theodolite using the formula:

$$X_< = \frac{f}{n}$$

Description:

$X_<$	:	Average angle difference
f	:	Total angle difference
N	:	Number of Observations

$$X_< = \frac{19^\circ\ 39'\ 0.033''}{5}$$

$$= 03^\circ\ 55'\ 0.055''$$

The average difference in angle of qibla direction measurement utilizing smartphone compass sensor with theodolite tool is 03° 55' 0.055''. To find out how significant the deviation of the qibla direction angle is from the compass sensor on Smartphones, it may be done by converting the average value of the angle difference into distance units, using the following formula:

$$L = \frac{S 2\pi R}{360}$$

Description:

L	:	Distance
S	:	Average angle difference
R	:	Earth radius

$$L = \frac{03^\circ\ 55'\ 0.055''\ x\ 2\ x\ 3.141592654\ x\ 6378\ km}{360}$$

$$= 437.6815289 \text{ km}$$

The qibla direction angle from the smartphone compass sensor to the qibla direction of theodolite in units of distance is 437,6815289 km.

The value of the storage angle is, of course, quite enormous since it has surpassed the minimal tolerance limit for the deviation of the qibla direction. According to the notion of *ihtiyathul qiblat*, the minimal tolerance for the deviation of the qibla direction is just 45 kilometers. Based on this study, the findings suggest that identifying the qibla direction using the compass sensor on a Smartphone has a weak degree of accuracy.

D. Conclusion

Determining the direction of the qibla using a smartphone must be done with prudence. This is because the compass sensor is readily impacted by the surrounding magnetic field exactly as a compass instrument in general. In addition, human error is hugely influential on the degree of accuracy. Compass sensor embedded in each brand and smartphone has varied specs and capabilities. So it has variable accuracy based on the kind and brand of smartphone utilized.

The results of the qibla direction accuracy test from the smartphone compass sensor that the magnetic declination value has adjusted with the qibla direction from the theodolite has an average angle difference of 03° 55' 0.055". This value does not surpass the minimal tolerance limit according to the concept of *Jihah qubro*, which is 180° and *Jihah sughro* with a tolerance of 90°. However, if the angle difference is converted into a distance unit, it is 437.6815289 km. This value is substantial since it has surpassed the minimal tolerance for deviations from the qibla direction according to the Ma'rufin Sudibyo's *ihtiyathul qiblat* concept, which is 45 kilometers.

Based on the analysis of study findings, it can be determined that the measurement of the qibla direction using a compass sensor or magnetic orientation on a smartphone has a weak degree of accuracy, despite modifications that have been applied to the magnetic declination value. Finding the qibla direction using a smartphone-based on compass sensor (magnetic orientation) should only be utilized when in an emergency. Meanwhile, to find the qibla direction in a permanent construction such as a mosque, it is advised to use a measuring instrument that has a high degree of precision, such as using a theodolite by utilizing the location of celestial bodies as a reference.

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