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Deviation of Qibla Direction

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ABSTRACT

Since the earth is not a sphere and neither flat whereas it is a geoid, we have difficulties in obtaining accurate qibla direction. In this study, two methods are compared in determining the deviation of distance if there is one degree deviation from the exact angle toward Ka'bah. The two methods are circumference equation (CE) and astronomical algorithm (AA). The measures of the distance towards Ka'bah from several mosques in Penang were calculated and compared. We found that it is best to use the astronomical algorithm while the circumference equation are not compatible in obtaining the shortest distance on earth surface.

Keywords: Qibla Direction, Astronomical Algorithm, Circumference Equation

INTRODUCTION

The qibla is the direction to the Ka'bah, but what precisely is that direction? Sheikh Muhammad S Al-Munajjid (2011, 19 july**, '**They discovered that their mosque deviates from the qiblah by 17 degrees'). A source 'Islam question and answer' website stated that the one who is close to the Ka'bah is required to face it head on, but the one who is far away from it must face its direction according to the majority of Islamic scholars. However, if one does not have any information about the direction of the qibla, the direction is between west and east. If there is any guidance or a village nearby, one must ask and find out about the qibla direction. It is our obligation to face the Ka'bah because it is one of the conditions of the prayer.

Ibn Qudamah Rahimullah (may Allah have mercy on him) said in al-Mughni (the most widely known textbook of Hanbali fiqh): Facing the qibla is a condition of prayer being valid, and there is no difference between both in compulsory prayer or Sunnah prayers. Hence, finding the qibla accuracy is crucial for Muslims to face the correct direction and to fulfil our worship to Allah.

In this paper, five mosques are treated. Qibla direction for these places is determined and distance between Makkah and these places are computed using the methods of CE and AA. Data for longitudes and latitudes used here are collected from[1] and are expressed in degrees and minutes.

Shape of the Earth

John P. Snyder based on the publication of the U.S. Geological Survey Professional Paper 1395 stated that the earth is not sphered and also not exactly an ellipsoid. They named the earth's shape as a geoid with assumption that all measurements are at mean sea level. The elevations and contour lines on the earth are relatively to the geoid but not ellipsoid. However, the latitude, longitude and all plane coordinate systems are determined with respect to the ellipsoid [2].

Jean Meeus in his book "Astronomical Algorithms" stated that in order to obtain most astronomical and geographical purposes, consideration for earth to be an ellipsoid of revolution is crucial. Since all plane coordinate systems are based on the ellipsoid, the earth's shape is assumed to be an ellipsoid of revolution for the simplification in our system [3]. Moreover, a geoid is a shape of sphere with flattening at the poles which is similar to the ellipsoid. Hence, we consider it as an ellipsoid of revolution.

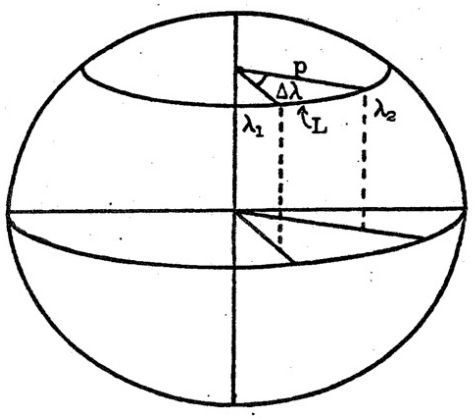

Figure 1: Parallel Arc Length
Source: (Richard H. Rapp, 1991 [4])

Drs. A. Jamil stated that geocentric or centre of the earth is a distance between the centre and the surface of the earth [5].

Latitude, Longitude And Its Radius

The earth has the length of an arcdegree of north–south latitude difference, which is approximately about 60 nautical miles, 111 kilometres or 69 statute miles at any latitude. To be exact, when a dergree changes at the pole, it gives one percent more distance than one degree changes at the equator. Meanwhile, the length of an arc degree of east-west longitude difference is about the same at the equator as the north-south, reducing to zero at the poles.

As of the latest revision, the WGS 84 (World Geodetic System 1984) datum surface is defined as an oblate spheroid (ellipsoid), with major (transverse) radius a = 6,378,137 m at the equator and flattening f = 1/298.257223563. The polar semi-minor (conjugate) radius b can be derived by b = a (1 - f) ≈ 6356752.3142 m. (This is a flattening of 21.384 685 755 km, or ≈ 0.335% in relative terms). Jean Meeus on his book titled astronomical algorithm stated that the parallel of latitude ϕ is a circle whose radius is [3]:

$$R_p = \frac{\alpha \cos \phi}{\sqrt{1 - e^2 \sin^2 \phi}} \tag{1}$$

Table 1: The degree length of latitude

Latitude	N-S radius of curvature *M*	Surface distance per 1° change in latitude	E-W radius of curvature *N*	Surface distance per 1° change in longitude
0°	6335.44 km	110.574 km	6378.14 km	111.320 km
15°	6339.70 km	110.649 km	6379.57 km	107.551 km
30°	6351.38 km	110.852 km	6383.48 km	96.486 km
45°	6367.38 km	111.132 km	6388.84 km	78.847 km
60°	6383.45 km	111.412 km	6394.21 km	55.800 km
75°	6395.26 km	111.618 km	6398.15 km	28.902 km
90°	6399.59 km	111.694 km	6399.59 km	0.000 km

METHODOLOGY

There are several ways in determining our qibla direction which are modern techniques and traditional techniques. In each way have a several methods. By traditional technique, the methods are by using constellation of stars, by using the sun, moon phase method, daily sun path method, and by using the final chamber. On the other hand, the modern techniques introduced the calculation of the qibla direction with scientific calculator, algorithm by Sheikh Tahir Jalaluddin, by using teodolit, by using prismatic compass, by using Rubu' Mujayyab and by using astrolabe.

The research is focus on modern approach toward our qibla direction. Hence the Spherical Trigonometry Method (STM) will be considered to obtain the qibla direction in each district mosque in Pulau Pinang [6]. Further details about spherical trigonometry refer to [7].

Table 2: The Azimuth of District Mosque in Pulau Pinang

No.	Mosque Name	Latitude	Longitude	Qibla Direction (STM)	N-S radius of curvature	E-W radius of curvature
1	Masjid Daerah Barat Daya	5° 20' 32"N	100° 13' 41"E	291° 37' 14"	6336.957	6387.695
2	Masjid Daerah Perda	5° 22' 06"N	100° 26' 10"E	291° 35' 01"	6336.965	6387.695
3	Masjid Daerah Butterworth	5° 29' 29"N	100° 23' 03"E	291° 31' 30"	6337	6387.71
4	Masjid Daerah Seberang Perai Selatan	5° 12' 41"N	100° 28' 41"E	291° 39' 37"	6336.92	6387.719
5	Masjid Negeri	5° 24' 34"N	100° 18' 45"E	291° 34' 33"	6336.976	6387.703

Source: (Noorashimah Ismail, 2007 [8])

There are two methods discovered in order to determine the distance if there is exist such deviation towards our qibla direction. First is by using the Astronomical algorithm which introduced by Jean Meeus in his book. Most of the researchers find that the equation used by him is more practical and easier to understand. His approach is towards shortest distance between two points measured along the earth surface by using trigonometric measurements. Secondly is by the circle circumference which indicated that to obtain a distance on the earth surface, we may assume that earth is a sphere and the distance is determined by using the circumference formula.

Astronomical Algorithm (geodesic distance)

The Geodesy distance introduced by H. Androyer gives a better accuracy in obtaining the shortest distance on the earth surface. Most researchers also find it handy in determining the distance between two locations on the earth surface. The distance between two points given by

$$S = D\,(1 + fH_1 \sin^2 F \cos^2 G - fH_2 \cos^2 F \sin^2 \mathrm{G})$$

Where the other variable calculated from

$$F = \frac{\phi_1 + \phi_2}{2} \qquad G = \frac{\phi_1 + \phi_2}{2} \qquad \lambda = \frac{L_1 + L_2}{2}$$

$$S = \sin^2 G \cos^2 \lambda + \cos^2 F \sin^2 \lambda$$

$$C = \cos^2 G \cos^2 \lambda + \sin^2 \mathrm{F} \sin^2 \lambda$$

$$\tan \omega = \sqrt{\frac{S}{C}}$$

$$R = \sqrt{\frac{SC}{\omega}}$$

$$\mathrm{D} = 2\omega\alpha$$

$$H_1 = \frac{3R - 1}{2C} \qquad H_2 = \frac{3R + 1}{2S} \tag{2}$$

Table 3: The geodesic distance according to its radius of curvature

No.	Mosque Name	Qibla Direction (STM)	Distance to Kaabah(km)	Distance if exist one degree deviation	Distance differ(km) from mosque to mecca	Distance away from Kaabah (if exist 1° deviation) (km)
1	Masjid Daerah Barat Daya	291°37'14"	10690.39	31204.17	20513.78	186.6
2	Masjid Daerah Perda	291°35'01"	9946.846	26612.19	16665.34	173.623
3	Masjid Daerah Butterworth	291°31'30"	8508.889	24703.25	16194.36	148.523
4	Masjid Daerah Seberang Perai Selatan	291°39'37"	11951.47	28052.45	16100.98	208.61
5	Masjid Negeri	291°34'33"	8724.096	27321.78	18597.68	152.28

*With possible error of 50m

Source: (Jean Meeus, 1991)

The calculation consider the radius at each district mosque which give average radius around 6336.97-6337 km north-south and a constant 6387.7km of east-west radius of curvature. The distance from each district mosque with Ka'bah is calculated in order to obtain the distance of one degree deviation by using the basic trigonmetric angle of the phytogoras theorem

$$\tan\theta = \frac{y\,(km)}{distance\ to\ Kaabah\ (km)} \tag{3}$$

Circle Circumference

$$circumference = \frac{\theta}{360}\,2\pi r \tag{4}$$

In this method, we assumed that earth is a sphere with a standard radius according to where it's situated. If we consider the distance from each district mosque to Ka'bah through the center of the earth it will gives differ circularly around the Ka'bah where the radius from Ka'bah to the center of the earth is 6353.38 north to south and 6389.951east to west.

Hence, if there is one degree deviation in our qiblah direction, the distance that differs will cause 110.9398km north to south of Ka'bah and 111.5257km east to west of Ka'bah.

CONCLUSION

There are various methods in obtaining the distance between Masjid al-Haram and our district mosques if 1^0 deviation exists in our qibla direction. When we face one degree away from our qibla direction it will deviate a distance from 148.523km to 173.623km based on astronomical algorithm method while it will deviate a distance from 110.9398km north to south and 111.5257km east to west of Ka'bah by the circumference equation. Meanwhile the plane distance gives 238.21km to 240.156km

deviation when exist a degree deflected away from our qibla direction. Based on Jabatan Mufti Pulau Pinang stated that approximately 150km will deviate if exist one degree of deflection. Hence the most acceptable distance is that introduced by the method of astronomical algorithm. Moreover, Androyer stated that it will give the closest relative error in the order of the earth flattening which will increase the accuracy in the calculation.

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