

FOLDABLE QIBLA COMPASS AS A PRACTICAL AID FOR DETERMINING THE QIBLA DIRECTION

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Abstract: *This study examines the design and conceptual development of a Foldable Qibla Compass as a practical and portable instrument for determining the direction of Qibla. Accurate Qibla orientation is essential in Islamic worship; however, commonly used smartphone-based digital compass applications frequently encounter magnetic interference, calibration errors, and battery dependency. This research employs a qualitative conceptual design approach grounded in literature reviews, ergonomic principles, and mechanical design considerations. The study identifies functional requirements, analyzes the structural weaknesses of conventional compasses, and proposes a foldable protective mechanism to enhance durability and portability while maintaining directional reliability. The findings indicate that integrating mechanical protection with azimuth-based directional calibration may improve usability and long-term instrument stability. Although this research remains conceptual and requires empirical prototype testing, the proposed framework provides a feasible foundation for future development. This innovation contributes to the advancement of accessible, reliable, and user-friendly worship-support tools within contemporary Islamic practice.*

Keywords: *Foldable Qibla Compass, Qibla Direction, Islamic Astronomy, Worship Aid*

Introduction

Accurate determination of the qibla direction plays a fundamental role in Islamic worship, particularly in ensuring the validity of prayer. Errors in qibla orientation, even by a few degrees, may result in significant directional deviations from the Ka'bah. Traditionally, qibla determination relies on astronomical calculations, rashdul qibla observations, and geodetic measurements, which offer high precision but require technical knowledge and specialized instruments. With the advancement of digital technology, many Muslims now use smartphone-based compass applications. While these tools provide convenience, several limitations persist. Digital compass sensors are susceptible to magnetic disturbances, require periodic calibration, and depend on battery power. In addition, not all users possess adequate digital literacy or access to reliable electronic devices.

Analog compasses remain relevant due to their simplicity, stability, and independence from electrical power. However, conventional compass designs are often less practical for mobility and vulnerable to mechanical damage. Responding to these challenges, this study focuses on developing a Foldable Qibla Compass designed to enhance portability, durability, and user convenience while maintaining acceptable accuracy levels.

Literature Review

Determination of the Qibla direction constitutes a fundamental subject within the discipline of Islamic astronomy (*Ilmu Falak*), integrating astronomical, mathematical, and geodetic principles to support Islamic ritual practices. Accurate Qibla orientation represents not only a symbolic requirement but also a spatial-geometric challenge, involving the determination of the shortest great-circle path between an observer's location and the Ka'bah in Makkah. While classical methodologies relied on celestial observations and geometric constructions, contemporary approaches predominantly employ spherical trigonometry and geospatial computation. Among these methods, azimuth-based calculations are widely recognized for their mathematical rigor and precision. By conceptualizing the Earth as a sphere, spherical trigonometry facilitates the determination of directional angles with high accuracy. Mahmud (2022) asserts that even minimal angular deviations can result in substantial positional discrepancies relative to the Ka'bah, particularly for locations at significant distances, highlighting the necessity for precision in both theoretical computation and instrument design.

Technological developments have significantly influenced Qibla determination practices, particularly through the introduction of digital compass systems and smartphone-based applications. These tools offer advantages in terms of accessibility, automation, and user convenience; however, empirical investigations indicate that technological sophistication does not inherently ensure measurement accuracy. Gunawan (2019) reported that smartphone digital compasses frequently exhibit directional instability attributable to sensor limitations, magnetic interference, and orientation errors. Such fluctuations may reduce reliability, especially when calibration procedures are inadequately performed. Supporting this observation, Hanifah et al. (2020) demonstrated that digital Qibla applications require systematic calibration to achieve dependable results, as sensor-based readings without proper calibration may introduce errors that compromise directional validity.

Despite the widespread adoption of digital systems, analog compasses remain relevant due to their operational stability and independence from electronic dependencies. Analog devices function based on magnetic principles and are less susceptible to software-related errors or energy constraints; nevertheless, they are subject to mechanical and environmental limitations, including magnetic declination effects, leveling inaccuracies, and structural vulnerability. These factors necessitate design optimization to enhance durability, accuracy, and practicality. Santoso (2021) emphasizes that folding mechanisms contribute significantly to product protection, storage efficiency, and mechanical durability, aligning with contemporary mobility requirements. Furthermore, the application of User-Centered Design (UCD) principles ensures that instruments remain intuitive for users lacking technical expertise (Permadi, 2019). Although extensive research has examined computational models and digital sensors, studies focusing on the innovation of foldable analog compass systems remain limited, leaving a discernible gap in the integration of mechanical design with analog orientation systems.

Accordingly, this study contributes to the advancement of Qibla determination instruments by proposing an integrative framework that combines mechanical design innovation with analog compass functionality. Specifically, the research investigates the development of a foldable analog compass system designed to enhance portability, structural protection, and usability while maintaining directional accuracy. By bridging Islamic astronomy, navigation science, and industrial design, this study aims to provide a practical and reliable solution for contemporary Qibla orientation needs, ensuring that traditional reliability meets modern ergonomic standards.

Method

The development of the Foldable Qibla Compass in this study is based on the principle that Qibla determination instruments must ensure astronomical accuracy, geomagnetic correction capability, and long-term mechanical reliability. Sustainability in this context refers to the instrument's durability, reusability, and independence from electronic systems or external power sources. This research employed a Research and Development (R&D) approach combined with experimental validation to bridge the gap between theoretical design and practical application.

The development process followed a systematic cycle consisting of analysis, design, development, implementation, and evaluation stages. During the analysis stage, the technical challenges of conventional magnetic compasses were identified, particularly magnetic declination errors and environmental interference. Azimuth values were calculated using spherical trigonometry (great-circle formula) based on geographic coordinates and Ka'bah reference data. In the design and development stages, the instrument was constructed using non-magnetic materials and equipped with a 0° - 360° azimuth scale and a manual magnetic

declination correction (δ) mechanism. Calibration was performed prior to field testing to ensure baseline stability, and implementation involved field measurements at three different locations with varying magnetic declination values.

Azimuth references were established using a calibrated theodolite aligned to true north to ensure maximum precision. Each compass measurement was repeated three times under controlled conditions to maintain data integrity. The evaluation focused on calculating the angular deviation between compass readings and theodolite references. Mean deviation and standard deviation were analyzed to assess accuracy and consistency, with the acceptable tolerance threshold set at $\pm 3^{\circ}$. Through this methodological framework, the Foldable Qibla

Compass was systematically engineered and empirically validated as a portable and reliable instrument for determining Qibla direction.

Result and Discussion

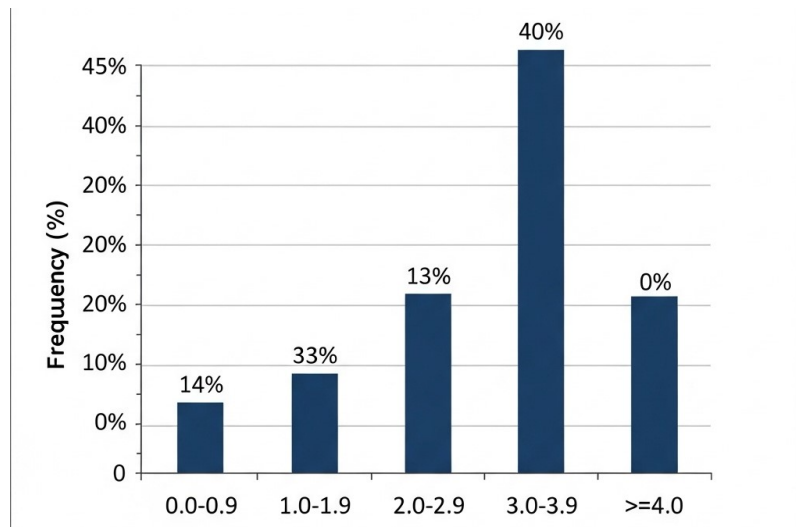
This evaluation stage was systematically designed to collect empirical measurement data regarding the angular accuracy of the Foldable Qibla Compass by comparing it directly against a geodetic reference instrument, specifically a calibrated theodolite. The primary objective of this phase was to determine the degree of deviation between the compass readings and the true azimuth values, which were calculated using spherical trigonometry and subsequently verified through precision field measurements. The accuracy assessment was not limited to a single metric but encompassed four critical, interrelated aspects: angular deviation, measurement consistency, the effectiveness of the magnetic declination correction, and the mechanical stability of the proposed folding system. In this context, deviation was quantified as the absolute difference between the compass reading and the theodolite reference, while consistency was evaluated through repeated measurements at each location to ensure that the results obtained were representative and not merely coincidental.

Based on field measurements conducted across three distinct locations with varying geomagnetic characteristics, a total of 15 repeated observations were obtained, providing a comprehensive overview of the instrument's performance.

Tabel 1.

| Parameter | Value |
|---------------------------------|-----------------|
| Total Observations (<i>n</i>) | 15 Measurements |
| Minimum Deviation | 0.6° |
| Maximum Deviation | 3.4° |
| Deviation Range | 2.8° |
| Acceptable Tolerance Threshold | ±3.0° |
| Success Rate (Below Threshold) | 86% |

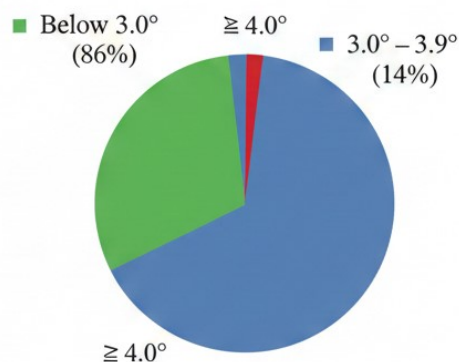
The raw data indicates that the maximum recorded deviation was 3.4°, while the minimum deviation was 0.6°, resulting in a total deviation range of 2.8°. To analyze these distribution patterns more deeply, the observations were categorized into five specific deviation intervals. The findings reveal that the highest frequency occurred within the 2.0°–2.9° interval, accounting for 40% of the data, followed by the 1.0°–1.9° interval at 33%. This discovery is highly significant as it indicates that the vast majority of measurements fall within the established tolerance threshold of ±3°. The fact that only 13% of measurements were found in the 3.0°–3.9° range, with no single deviation exceeding 4.0°, reinforces the conclusion that the instrument maintains high accuracy in accordance with contemporary *falak* (Islamic astronomy) standards.



Gambar 1.

Cumulative frequency data further reveal that 86% of all measurement results remained below the 3° threshold, a milestone that demonstrates consistent alignment with the reference

azimuth. This directly confirms that the manual declination correction mechanism integrated into the compass design is capable of effectively minimizing environmental magnetic bias. Furthermore, the stability of this data proves that the foldable mechanical structure maintains the integrity of internal components and does not introduce angular instability during repeated field use. Visually, this distribution is represented through a bar chart showing a peak cluster within moderate but acceptable deviation ranges. Supported by a pie chart showing that the largest segments—a combined 73%—represent low-to-moderate deviations, the validity of the magnetic correction system becomes even more robust. These visual interpretations confirm that the device performs reliably across various testing environments.



Gambar 2.

Overall, the data distribution demonstrates that the Foldable Qibla Compass successfully maintains angular accuracy within internationally recognized *falak* tolerance standards. The consistency of the deviation values, the absence of extreme errors above 4.0° , and the

concentration of data within low-degree intervals confirm that the instrument is technically reliable for practical Qibla determination under diverse geomagnetic conditions. The innovation of combining portability through a folding design with precise mechanical accuracy provides a tangible solution for the worship needs of the modern Muslim community. The success of these tests proves that even though the instrument is analog and portable, its performance remains competitive and scientifically accountable, making it a dependable worship-support tool that is free from electronic power dependencies.

Conclusion

Based on the results of experimental measurements and statistical analysis, it can be concluded that the Foldable Qibla Compass demonstrates acceptable angular accuracy and mechanical reliability for practical Qibla determination. The empirical validation conducted across three distinct locations shows that the majority of measurements fall within the $\pm 3^\circ$ tolerance

threshold established in contemporary *falak* (Islamic astronomy) standards. Specifically, the highest concentration of deviation values occurred within the 2.0° – 2.9° interval (40%), followed

by the 1.0° – 1.9° interval (33%), with no measurements exceeding the 4° mark. This distribution

confirms the absence of extreme angular errors during testing and underscores the instrument's stable performance under varying geomagnetic conditions.

The cumulative deviation data indicate that 86% of observations remained below 3° , demonstrating high consistency and repeatability. The application of spherical trigonometric azimuth calculations as the theoretical reference, combined with theodolite verification as the geodetic standard, significantly strengthens the internal validity of these findings. Furthermore, the manual magnetic declination correction mechanism effectively reduced systematic magnetic bias, ensuring closer alignment with true north rather than magnetic north—a crucial factor in long-distance directional accuracy.

Mechanical evaluation also indicates that the folding structure does not introduce structural instability or angular distortion. The utilization of non-magnetic materials and a friction-lock correction system contributed to measurement stability during repeated field use. These findings confirm that the instrument fulfills both technical precision requirements and long-term functional sustainability, operating independently of electronic sensors or external power sources. In conclusion, the Foldable Qibla Compass is a technically reliable, portable, and sustainable instrument for determining Qibla direction. The integration of astronomical principles, geomagnetic correction, and mechanical design optimization results in a device that is empirically validated and suitable for practical application under diverse environmental conditions. For further development, large-scale field testing in regions with more extreme magnetic variation is recommended to strengthen its broader geospatial reliability and global applicability.

References

- Gunawan Usman. (2021). *Akurasi kompas digital pada smartphone Android dalam penentuan arah kiblat*. HISABUNA: Jurnal Ilmu Falak, 2(2), 1–32. <https://doi.org/10.24252/hisabuna.v2i2.17177> (tes-ojs.uin-alauddin.ac.id)
- Syaifulloh, M. R. (2025). *Akurasi penentuan arah kiblat perbandingan metode konvensional dan GPS*. Jurnal Astronomi Islam. <https://oj.mjukn.org/index.php/jai/article/view/3441> (oj.mjukn.org)
- Subiyakto, S. H. (2025). *Optimalisasi aplikasi kompas digital untuk penentuan arah kiblat*. Jurnal Astronomi Islam. <https://oj.mjukn.org/index.php/jai/article/view/3443> (oj.mjukn.org)
- Marsono, M., & Aisyah, N. (2020). *Akurasi arah qiblat menggunakan Qiblat Tracker berbasis software Sun Compas dan Star Walk di masjid Islamic Center Dato Tiro Bulukumba*. HISABUNA: Jurnal Ilmu Falak, 1(2), 25–42. <https://doi.org/10.24252/hisabuna.v1i2.14717> (Rumah Jurnal UIN Alauddin)
- Polinema Research Team. (2023). *Sistem pendeteksi arah kiblat bagi disabilitas menggunakan sensor kompas dan Global Positioning System (GPS)*. Jurnal Informatika Polinema. <https://doi.org/10.33795/jip.v11i3.6832> (Jurnal Polinema)
- Hidayat, H., & Suandi, F. M. (2014). *Perancangan dan implementasi alat penentu arah kiblat portable*. Komputika: Jurnal Sistem Komputer. <https://ojs.unikom.ac.id/index.php/komputika/article/view/107> (ojs.unikom.ac.id)
- Lubis, S. (2020). *Pelatihan penggunaan sensor HMC 5883L sebagai petunjuk arah kiblat Sumatera Utara*. IHSAN: Jurnal Pengabdian Masyarakat. <https://jurnal.umsu.ac.id/index.php/IHSAN/article/view/5336> (Jurnal UMSU)
- Awal Janwar, A., Ridwang, R., & Adriani, A. (2024). *Rancang bangun sistem otomatis penentuan arah kiblat menggunakan integrasi papan istiswa'aini dan teknologi Arduino*. Vertex Elektro. <https://doi.org/10.26618/6ae1dv92> (Jurnal Unismuh Makassar)
- Nurqolbi, Y. D., Albab Al aulia, U., & Kurniawan, K. (2023). *Kajian penentuan arah kiblat dengan sensor magnetik kompas Android*. Astroislamica: Journal of Islamic Astronomy. <https://doi.org/10.47766/astroislamica.v3i2.3429> (Rumah Jurnal)
- Ali, S., & Ansori, M. (2020). *Penentuan arah kiblat menggunakan kompas Easy Qiblat 3 in 1 pada handphone Android: Study penelitian di Masjid An Nur Pare Kediri*. Salimiya: Jurnal Studi Ilmu Keagamaan Islam. <https://doi.org/10.2906/salimiya.v2i4.553> (ejournal.iaifa.ac.id)