The Importance and Potential of Golden Ratio in Architecture Design

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Abstract

The previous study of the Golden Ratio illustrates a less effective designer solution in terms of the use of geometry and aesthetic perception. Additionally, most designers who are unaware of the importance of the Golden Ratio have raised questions about their application in architectural design. As such, this paper focuses on two objectives by identifying the significant of the Golden Ratio in the superior design and daily objects and evaluating the importance and potential of the Golden Ratio to designers in architectural design. The methodology of the study included are content analysis, case studies of two mosques which are Parit Melana Village Heritage Mosque and Peringgit mosque. The expected results of the study include a harmony design is closely related to mathematical relations, the use of geometry and aesthetics, and designers can apply the Golden Ratio in architectural design.

Key Word : Golden Ratio, Mathematical Relations

1. Introduction

According to Akhtaruzzaman, Md. (2011), the relationship between proportion and good aesthetics has rise the discussions in science due to accidental occurrences. This is included in various object designs such as books, paintings, editions and so on. The design is estimated to be a rectangle where the ratio of length and width is equal to the Golden Ratio, \( \phi = (1 + \sqrt{5}) / 2 = 1.6180339887 \) (approx.). \( \Phi \) is also referred to as divine proportions, gold cross search, etc. which is the result of the division of segments into two segments (A + B) namely A / B = (A + B) / A = 1.6180339887 (approximately) where A > B.

Through the ages, there have been various factors influencing architecture such as mathematics, culture and religion. Most of the influence can be found in centuries-old architectural projects. The Golden Ratio is one of the mathematical rules that has a significant impact on design and end result. Among the examples that have Golden Ratio is the Parthenon with its column dimension ratio and Notre Dame Cathedral (AL Shirif, R. 2014). In addition to architecture in the historical context, the Golden Ratio can be seen in modern architecture (Kissinger, C. E. 2012). One of the important principles in modernism is to apply mathematics and ignore traditional styles, especially building elements (Salingaros, N. A. 2012). There is another calculation of the system that approaches the Golden Ratio which is the Fibonacci Series: 1, 1, 2, 3, 5, 8, 13 (Ching, F. D. K. 2007).
2. Objectives

a. To know the significance of the Golden Ratio in superior design and everyday objects to study the use of geometry and aesthetics in design practice.

b. To evaluate the importance and potential of the Golden Ratio to designers in the use of the Golden Ratio in the architectural design process.

3. Methodology

The scope of this study is centered on:

a. A more in-depth study of the Golden Ratio in everyday design and objects.

b. The analysis of the content of the Golden Ratio theory presented by experts.

c. Study the use of the Golden Ratio in architecture.

The chronology of the study methodology as follows:

Phase 1 - Theoretical Content Analysis

Phase 2 - Case Study

Phase 3 - Data Collection and Analysis

4. Content Analysis

Analysis of existing content as a starting point for research and critical thinking in design learning. This study focuses on the shortcomings in research, the implementation of the Golden Ratio knowledge in design. Next, respond to research objectives by studying the use of geometry and aesthetics in design and identify the use of the Golden Ratio as a measure in architecture. Content analysis is divided into four parts, namely:


b. Geometry in Science - Presents some existing research from various sources.

c. The Relationship of Geometry to the Fibonacci Series - Focuses on the use of Fibonacci numbers used for mathematical explanations and how Fibonacci sequences are relevant in the design process.

d. Golden Ratio in Architecture - Review the use of Golden Ratio in superior design and applied principles.

Phi and Its Relationship to Geometry

Golden Section

Referring to Figure 1 and Figure 2, for line segments, the Gold Section can be considered as the point where the line is divided into two parts containing the same ratio between the larger segment and the shorter segment. The ratio is about 1.6180339887 and is shown in Greek letters, \( \varphi \). The search for Gold Section is often said to be the most pleasing aesthetic point (Akhtaruzzaman, Md. 2011).

\[
\varphi = \frac{P}{q} = \frac{P + q}{P} = 1.6180339887 \text{ (approx.)}
\]
Golden Rectangle

The Golden Rectangle is divided into equal rectangles and equal squares (Akhtaruzzaman, Md. 2011). Referring to Figure 3, the process of proportionally reducing the rectangle produces the Golden Spiral.

Golden Triangle

The concept of Golden Triangle is very important because of the nature of pentagonal symmetry in the universe which is often taken as an initial step to investigate the mystery $\phi$ (Akhtaruzzaman, Md. 2011). Figure 4 shows two types of Golden Triangle.
A series of Golden Triangle will form the Pentagon, Pentagram, Decagon and Decagram as shown in Figure 5 and Figure 6.

**Figure 5:** Pentagon (Akhtaruzzaman, Md. 2011)

**Figure 6:** Decagon (Akhtaruzzaman, Md. 2011)

**Golden Angle and Golden Ellipse**

The Golden Angle is categorized as a circle divided into two proportions of the Golden Ratio, where it is marked 137.5 degrees. Golden Ellipse is an ellipse drawn in the Golden Rectangle(Akhtaruzzaman, Md. 2011). Figure 7 shows the Golden Spiral formed in the Golden Triangle.
Dynamic Rectangle

Based on the number of ratios, a rectangle can be categorized as a static rectangle or a dynamic rectangle. Static rectangles have rational fraction ratios such as 1/2, 2/3, 3/3 etc. while dynamic rectangles have irrational fractions such as $\sqrt{2}$, $\sqrt{3}$, $\sqrt{5}$, $\varphi$ in Golden Section (Akhtaruzzaman, Md. 2011). Based on Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12, Dynamic Rectangle produce a harmonious visual subdivision.
Geometry in Science

This section will discuss examples of research that studies the geometric relationship between the natural and man-made worlds. Geometry is one of the oldest sciences and branches of mathematics that has been widely used in art, architecture and design since Egyptian and Greek times.

‘Geometry deals with pure form, and philosophical geometry re-enacts the unfolding of each form out of a preceding one. It is a way by which the essential creative mystery is rendered visible. The passage from creation to procreation, from the unmanifest, pure, formal idea to the 'here-below', the world that spins out from that original divine stroke, can be mapped out by geometry, and experienced through the practice of geometry’ (Lawlor 1982, p.10).

Meaning:

Based on analysis, geometry means measurement of the earth’ and ‘the study of space through the measurement and relationship of shapes’ (Lawlor 1982).

Artists, architects and designers have used geometry as the basic theory for works of art. Adrian Bejan, a professor of mechanical engineering at Duke University has studied how living organisms are formed.

‘For a finite size flow system to persist in time (to live), its configuration must evolve in such a way that provides easier access to the currents that flow through it’ (A. Bejan 2012, p.3).

Meaning:

His Theory of Construction Law is the first physical principle to explain natural design and predict future design developments. It states that every flow system is destined to remain imperfect as nature evolves. Bejan used the Golden Ratio Constructing Law to design a rectangular image and found the design part approaching the Golden Ratio.
The Relationship of Geometry to the Fibonacci Series

This section examines the relationship between Fibonacci sequences in nature and geometry. Often artists and designers are inspired by geometric patterns and sometimes mimic the shapes of plants and animals. This may be due to nature which displays a perfect balance in terms of the principles of unity, symmetry and asymmetry.

'Any plant curve proceeding from a fixed point (or pole), and such that the vectoral area of any sector is always a gnomon to the whole preceding figure, is called an equiangular, or logarithmic, spiral… it is characteristic of the growth of the horn, of the shell, and of all other organic forms in which an 32 equiangular spiral can be recognized, that each successive increment of growth is similar, and similarly magnified, and similarly situated to its predecessor, and is in consequence a gnomon to the entire pre-existing structure'(Thompson 1917, p.184).

Meaning:

Thompson's spiral geometry investigates the relationship between geometry and numerology in living organisms. The biological laws of the growth of animals, plants and living organisms, evolve without changing shape and only increase in the Golden Ratio.

‘At the center of the tip is a circular region of tissue called the“ apex ”; around the apex, one by one, tiny lumps form, called “primordial.” Each primordium migrates away from the apex-more accurately, the apex grows away from the lump, leaving it behind — and eventually, the lump develops into a leaf, petal or the like. Moreover the general arrangement of those features is laid down right at the start, as the primordia form. So the heart of the problem is to explain why you see spiral shapes and Fibonacci numbers in the primordia, as all the varied Fibonacci features of plants are simple consequences of this basic geometric structure’ (Stewart 1998, p.124).

Meaning:

According to Stewart 1998, the Fibonacci Series will appear in any nature, leaf arrangement, plant branch or even rabbit breeding pattern. Ian Stewart explains in his book 'Secrets of Another Life', Phyllotaxis (arrangement of leaves on plant stems) has found a connection between botanical spiral patterns.

The Fibonacci series is closely related to the Golden Angle. Golden Angle is the principle of arrangement of leaves and branches in many plants including sunflower seed heads as shown in Figure 13.

![Figure 13: Sun Flower (Hyo Jin Koh 2014)](image)

It is not only plants that display this principle. Referring to Figure 14, the length of human bones in the fingers, hands and arms shows the relationship with the Fibonacci Series (Lawlor 1982).

![Figure 14: The length of the human bone in the finger (Lawlor 1982)](image)

‘Sensory systems generally have a very mathematical structure. Why? Senses have to process incoming data rapidly and reliably to extract information about the outside world. To do this they must be engineered rather carefully. They must respect the underlying patterns of the outside world ’(Stewart 1998, p.160).
Meaning:

According to Steward 1998, sensory systems are said to be related to mathematical structure. Geometric symmetry is the principle of proportional shape in art, design and science used to understand the nature of the universe. Geometric proportions in design can express emotions as well as logical through harmonious proportions. Geometry can indeed develop practical applications and not just aesthetics.

Golden Ratio in Architecture

The relationship between mathematics and nature in architecture is a significant point in history. Many argue that the Ancient Egyptians used the Golden Ratio first on the pyramid building as shown in Figure 15.

![Pyramid building](image1.png)

Figure 15: Pyramid building (Gangwar, Gaurav & Fellow, Research & Prof, Asstt. 2017)

Phidias (500 BC - 432 BC), a Greek sculptor and mathematician, studied Phi and used it to design sculptures for the Parthenon as in Figure 16.

![Parthenon](image2.png)

Figure 16: Parthenon (Bozinoff, M. 2015)

Plato (c. 428 BC - 347 BC), in his view of natural science and cosmology presented in ‘Timaeus’, considered the Golden Ratio to be the binder of all mathematical relations and the key to cosmic physics.

Euclid (365 BC - 300 BC), in ‘Element’, refers to the division of the line at point 0.6180399. This in turn gives rise to the use of the term Golden Mean. He also linked this number with the use of pentagrams.

During the medieval Renaissance, Modernism, many architects used the Golden Ratio in design. Famous buildings include the CN Tower in the Renaissance.

Principles of Geometry in Architecture

There are many pioneering architects whom have developed a proportion system in architectural history such as Vitruvius in Roman times, Leon Battista Alberti in the Renaissance and Le Corbusier in the 20th century.
According to the Roman architect Vitruvius, an architect had to consider three main aspects of design in construction, namely firmness (strength), utility (function), and venustas (beauty). Based on Figure 17, he believes that the proportions of the human body are perfectly created by nature and can be used to design buildings.

![Vitruvius Man](image1)

**Figure 17: 'Vitruvius Man by Leonardo da Vinci' (Gangwar, Gaurav & Fellow, Research & Prof, Asstt. 2017)**

Alberti explains that a harmonious proportion can be achieved in this way:

‘Nothing could be added, diminished or altered except for the worse’ (Alberti, Leon Battista 1967).

‘What is pleasing to the ear should be pleasing to the eye’ (Alberti, Leon Battista 1967).

**Meaning:**

According to Alberti, in order to achieve perfection in the proportion system, one must explore several options before the best search. He also thinks anything pleasant to the ear will please the eye through the scale of the music. Referring to Figure 18, he has applied a system of geometric proportions to the Santa Maria Novella building in Florence.

![Geometric proportions](image2)

**Figure 18: Geometric proportions on the visible part of Santa Maria Novella in Florence (Gangwar, Gaurav & Fellow, Research & Prof, Asstt. 2017)**

Le Corbusier has taken advantage of the knowledge gained by Vitruvius and Leone Battista Alberti and subsequently interpreted this knowledge in a new way called ‘Modulor’. All anthropometric human activities can be obtained through ‘Modulor Man’ as shown in Figure 19.
Based on content analysis, work involving the relationship between geometry in science, art and design facilitates an understanding of nature and man-made nature. Golden ratio and aesthetic beauty are among the core principles that can be used effectively in design.

Moreover, geometry can be said to be a bridge that connects art, science and design. The principles of geometry in the design process can help designers think of visual composition and analyze design to enhance creativity.

5. Case Study 1

In line with exploratory studies, case studies are chosen as strategy. The location chosen is in Malacca, a historic city and the proof of the use of the Golden Ratio can be carried out based on UKM 2018/2019 measured drawings.

Case studies on the ParitMelana Village Heritage Mosque and the Peringgit Mosque conducted because there are diversity in terms of its architecture and historical value related to the use of the Golden Ratio which is not emphasized by the current designers.

The first case study selected for the study of architecture and the use of the Golden Ratio is the ParitMelana Village Heritage Mosque in Alor Gajah, Malacca. Referring to Figure 20, the site of this mosque is located in ParitMelana Village, Durian Tunggal, Malacca and is located near the Beringin, BelimbingDalam and Krubong areas.
The Original Form of the ParitMelana Village Heritage Mosque

ParitMelana Village Heritage Mosque has a rectangular floor plan along with 14 pillars that formed the structure of the mosque. Mosque worshipers can enter this mosque through the three doors on the front, back and sides of the mosque. The roof of the mosque is the roof of 'meru'. On the roof, there are decorative elements that are shaped by Chinese architecture.

All parts of the mosque are built by the locals using wood. The wood source used for construction is from the nearby forest (Merlimau Polytechnic 2018). Figure 21 shows the original condition similar to ParitMelana Village Heritage Mosque while Figure 22 shows its condition after renovation.

Figure 21: The original condition of a mosque in Alor Gajah which is similar to the situation like the ParitMelana Village Heritage Mosque (Menora2010)

Figure 22: ParitMelana Village Heritage Mosque which has been renovated (UKM Measured Drawings 2018/2019)
Use of Golden Ratio at ParitMelana Village Heritage Mosque

Figure 23: Golden Ratio on the Roof Plan of ParitMelana Village Heritage Mosque using Basic Golden Ratio (UKM Measured Drawing 2018/2019)

Through the Basic Golden Ratio method, the use of rectangular proportions on the roof plan can be seen through Figure 23.

Figure 24: Original Floor Plan of ParitMelana Village Heritage Mosque using Phi Grid (UKM Measured Drawing 2018/2019)
Figure 25: Golden Ratio on the Original Floor Plan of ParitMelana Village Heritage Mosque using Phi Grid (UKM Measured Drawing 2018/2019)

Referring to Figure 25 and Figure 26, the division of prayer space can be determined using Phi Grid. The location of the column is the basic reference in this division of space.

Figure 26: Front Elevation of ParitMelana Village Heritage Mosque using the Golden Rectangle (UKM Measured Drawing 2018/2019)

Figure 27: Golden Ratio on Front Elevation of ParitMelana Village Heritage Mosque using Golden Rectangle (UKM Measured Drawing 2018/2019)

Based on Figure 26 and Figure 27, the smaller Golden Rectangle method shows the ratio of height and width of column.
Referring to Figure 28 and Figure 29, Golden Rectangle is used comprehensively to determine the height of the roof and the proportion of building to the roof.
Based on Figure 30 and Figure 31, the intersection point of Phi Grid can determine the position of the window as well as the position of the 'Mihrab'.

Figure 32: Right Elevation of ParitMelana Village Heritage Mosque using Golden Rectangle (UKM Measured Drawing 2018/2019)

Referring to Figure 32 and Figure 33, the Golden Rectangle can determine the height of the second layer and the third layer of the roof of the mosque.

Figure 33: Golden Ratio on Right Elevation of ParitMelana Village Heritage Mosque using the Golden Rectangle (UKM Measured Drawing 2018/2019)

Figure 34: Right Elevation of ParitMelana Village Heritage Mosque using Phi Grid (UKM Measured Drawing 2018/2019)
Based on Figure 34 and Figure 35, through the intersection of Phi Grid, the position and height of the building including the columns can be identified.

Referring to Figure 36 and Figure 37, the use of Basic Golden Ratio can be seen in terms of proportion from floor to roof.
Based on Figure 38 and Figure 39, the use of Golden Rectangle can determine the size and height of the door.
Referring to Figure 40 and Figure 41, the emphasis on the part of the central space where the columns used as the focus of space can be identified through the method of using Phi Grid.

6. Case Study 2

The second case study, Peringgit Mosque is located at the foot of Bukit Peringgit, in a slightly undulating area. Referring to Figure 42, the site was later developed into an intersection to Solok Pantai Peringgit and the road to Bukit Peringgit. Peringgit Mosque then became the center of the community to perform worship and became a gathering place for Friday prayers (Mohamad, R. 2002).

The origin of the name comes from the word Feringgi, the nickname of the Portuguese by the Malays. The Portuguese colonizers also built a fort at the top of Peringgit hill. Peringgit predominantly Malay and the majority of the population who still live in it until the acquisition by Dutch Malacca from the Portuguese (Samat,
K.2018),(Surat, M.2018) argues that the Peringgit Mosque has architectural influences from Java. Based on the shape of the roof, the traditional mosque in the Peninsula can be divided into four. The first type is a mosque that has a three-layered roof. This type of mosque can be seen at Kampung Laut Mosque, Kampung Pantai Mosque, Chenor and many other traditional mosques throughout the Peninsular. This multi-storey roof is called meru roof (Ahmad, A. A. 2015).

Figure 43: Position of the four types of pillars in the space of the Peringgit Mosque (UKM Measured Drawing 2018/2019)

Figure 44: Roof with three layers (UKM Measured Drawing 2018/2019)

The Use of the Golden Ratio at the Peringgit Mosque

Figure 45: Golden Ratio on Floor Plan of Peringgit Mosque using Basic Golden Ratio (UKM Measured Drawing 2018/2019)
Referring to Figure 45, the use of Basic Golden Ratio can determine the proportion of prayer space in the same square.

Figure 46: Floor Plan of Peringgit Mosque using Basic Golden Ratio (UKM Measured Drawing 2018/2019)

Based on Figure 46 and Figure 47, Basic Golden Ratio can determine the position of the doors.

Figure 47: Golden Ratio of Peringgit Mosque Floor Plan using Basic Golden Ratio (UKM Measured Drawing 2018/2019)

Figure 48: Floor Plan of Peringgit Mosque using Phi Grid (UKM Measured Drawing 2018/2019)
Referring to Figure 48 and Figure 49, through the intersection point of Phi Grid, the position of the columns can be identified.

Based on Figure 50 and Figure 51, Phi Grid can determine the placement of columns and entrance.
Figure 52: Back Elevation of Peringgit Mosque using Basic Golden Ratio (UKM Measured Drawing 2018/2019)

Figure 53: Golden Ratio on Back Elevation of Peringgit Mosque using Basic Golden Ratio (UKM Measured Drawing 2018/2019)

Referring to Figure 52 and Figure 53, the Basic Golden Ratio method can determine the proportion of the mosque from floor to roof.

Figure 54: Back Elevation of Peringgit Mosque using Golden Rectangle (UKM Measured Drawing 2018/2019)
Based on Figure 54 and Figure 55, the smaller Golden Rectangle can determine the height of the railing.
Referring to Figure 56 and Figure 57, Phi Grid can determine the height of the top layer roof of the mosque and the position of the columns.

![Figure 58: Cross Section A-A of Peringgit Mosque using Phi Grid (UKM Measured Drawing 2018/2019)](image)

Based on Figures 58 and 59, the use of Phi Grid, emphasizes the proportions in the middle space where the columns as the focus of space.

The result can be drawn from the case studies of both mosques that the harmony of the whole building from floor to elevations can be achieved based on the use of Golden Ratio. The design looks perfect not due to the use of expensive materials but based on the principle of proportion. The key elements that contribute to design harmony are closely related to mathematical and aesthetic relationships.

7. Discussion

Proportion is a major subject in architectural theory. Rules and principles should be considered for aesthetic purposes. Design not only sketches but also to find the beauty of shape and harmony with space. Mathematics and geometry form the basis of aesthetic value in designing. The relationship of the ratio between the numbers in determining the Golden Ratio is indeed worth considering.

Architects often go through a lengthy design process due to various factors that need to be considered. Among the factors involved include site study to find out the potential of the surrounding conditions as well as the design that suits the occupants without neglecting comfort and aesthetic value. The use of Phi, and other visual harmony, is an appropriate measure in contemporary design. Grids, compositions, hierarchies, layouts and shapes.
are among the identifiable elements (Darrin Crescenzi 2015). The Golden Ratio is a principle of organizing a composition that can be felt rather than understood.

The Golden Ratio is often used in design due to its ergonomically related relationship. Design is a very subjective profession. Therefore, the Golden Ratio should be used as a measure in architecture because its application brings beauty and harmony in the overall design.

8. Summary/Conclusion

Based on the study, the Golden Ratio can produce a superior design. The use of geometry and aesthetics can be identified in all everyday objects. The Golden Ratio is very important for designers in the process of architectural design to produce a harmonious and prominent design.

The main elements that contribute to the harmony of design are closely related to mathematical relationships, the use of geometry and aesthetics. The overall harmony of the building from floor to elevations can be achieved based on the use of the Golden Ratio. Designers can apply the Golden Ratio in architectural design. With all its unique mathematical features, the Golden Ratio will not only be the basic principle of beauty and harmony in nature but also in the field of architecture. The Golden Ratio will continue to open new doors in the understanding of life and the universe.

The use of the Golden Ratio as a measure in architecture will continue to be explored by young designers as well as more comprehensive studies can be continued.

References