

The Golden ratio and its impact on Architectural design

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Abstract:

Proportionality is a concept that refers to the importance of the relationships between the parts of the same geometric shapes in terms of a mathematical ratio, which is represented here by the golden ratio, and relying on mathematical principles in art and architecture gives the human mind the ability to perceive and understand the relationships between blocks and spaces in a simpler way. Therefore, balance, proportionality and symmetry are among the basic principles in Architectural Design. Proportionality in this way can be considered a numerical value expressing how the design elements are located within its general framework. Therefore, the research was interested in studying the concept of golden ratios and their relationships with basic geometric shapes through mathematical relations represented in the Fibonacci sequence and its applications in architecture throughout the ages through the use of the deductive approach and then the use of the inductive approach in order to find a mathematical technique that helps architects achieve golden proportions in their architectural designs through find an architectural module (grid) that achieves the Fibonacci sequence and thus achieves the golden ratios in the form of the relationship between the sides of the architectural spaces. Then the research used the experimental method to apply the proposed technique to an existing residential villa by studying the design spaces of the villa before applying the proposed architectural module, then modifying the architectural design of the villa according to the proposed architectural module and then drawing conclusions and recommendations.

Keywords:

Golden ratio, Architectural Design, Fibonacci sequence, Architectural Module (Grid).

Paper received 19th November 2021, Accepted 18th January 2022, Published 1st of March 2022

Introduction:

The golden ratio or the divine ratio has been applied in many works, whether artistic or in the field of architecture and medicine, and it is a mathematical theory that measures the proportionality between two elements within the design so that the value of this ratio is "1.618", where a lot of research has been done to trace the roots of the emergence of the golden ratio where it was found in Nature, including the spiral arrangement of leaves and other plant parts or the shape of tornadoes (Hashemiparast & Hashemiparast, 2011).

Researchers have been interested in studying the architectural applications of the golden ratio, especially in ancient civilizations, where many theories emerged about the construction of the Great Pyramid in Giza (around 2570 BC) and the ancient Egyptian architect's use of the golden ratio in building the Great Pyramid (Meisner, 2016).

In the twentieth century modernist architecture, artists and architects used the golden ratio, including Le Corbusier and Mies van der Rohe, where we find, for example, that Le Corbusier created a mule based on the Fibonacci sequence and the Vitruvian Man by Leonardo da Vinci to alternate his design with the golden ratio, especially the use of the golden rectangle, where the ratio of the longer side to the shorter side is the golden

ratio (Livio, 2008).

Research problem:

Many architects in the current era are not interested in finding proportional relationships between the geometric shapes used in the architectural design, which affects the aesthetic and engineering form and the discomfort of users within the architectural spaces, as well as the increase in the percentage of wasted spaces within the design, which increases the cost of construction.

Research objectives:

Finding a proposed mechanism that helps architects achieve proportionality between the relationships of architectural spaces in order to achieve aesthetic formation and visual and psychological comfort for users

Research Methodology:

To achieve this goal, the research followed the deductive approach to define the golden ratio or the divine ratio and the historical reference and examples of how to apply it in nature by identifying the Fibonacci sequence and its applications in architecture, whether in ancient civilizations or in the modern era, then the research followed the inductive approach with the aim of reaching it suggested to proposed technique helps architects achieve proportionality between geometric shapes in their designs for ease of perception by the human

mind, and thus achieve the aesthetic principle and comfort for users within the architectural spaces. Then the research followed the experimental method to apply the proposed technique to a design model in order to evaluate the proposed technique.

1. Definition of Architecture:

Architecture is one of the ancient engineering arts that man has known since the dawn of history, as he needed a shelter to protect him from harsh environmental conditions and to develop in him a sense of safety, as architecture is also known by applying engineering concepts and principles to meet the needs of society in a specific type of buildings according to the cultural characteristics of the place Or the society and heritage in the region, which makes it unique because it reflects the nature of architecture and human civilizations in every era.(Mavridou et al., 2016).

Humans were keen to take advantage of the

surrounding resources to turn them into habitable homes, and among the most important of these resources: mud, stones, and wood. During the population expansion witnessed by the succession of human eras, architecture was no longer limited to building housing, but rather included all buildings. Others, such as: markets, private shops, houses of worship, security centers, public service institutions, luxurious palaces, and major museums, which made architecture one of the most famous human arts that contributed to building a group of civilizations that survived until then.(Isa, Ismail, Zainol, & Othman, 2016).

The research is concerned with the types of buildings and the role of the architect, and the most important skills and duties that the architect must distinguish from other professions.



Figure 1: Architectural Building types. Source: (Faisandier, 2013)

1.1 Architecture Building Types:

The types of buildings depend on the cultures and needs of the peoples, so the division of the types of buildings depends on the community in the first place and then the architect is assigned the responsibility for creating the required buildings in terms of meeting the needs of users and achieving durability and aesthetic form (Martini et al., 2014).

The types of architectural buildings are classified according to the needs of the communities into local residential buildings, religious, governmental, recreational, educational, commercial and industrial. (Faisandier, 2013).

1.2 The role of architects:

The term "architect" has been around for many centuries, with the architect being a comprehensive profession as he was a painter, sculptor, engineer and builder, but with the complexities of modern technology a specialization has appeared in the architectural profession, where architects are seen as highly - qualified and educated professionals (Mavridou et al., 2016).

The function of architecture is one of the prominent functions due to the great technical development in methods and methods of construction, which allowed the application of many creative ideas that were not possible before, and the responsibility of the architect is not limited to the creative drawing of the buildings to be constructed, but the architect also works on analyzing the entire environment surrounding the building, and knowing the factors that may affect the method of construction such as wind, building floor, temperatures..etc. (Košir et al., 2018).

It is also committed to providing a clear idea and vision of the final shape and design of the building, taking into consideration meeting the needs of the users, studying the buildings and areas surrounding the building at the present time or even in the near future, and trying to ensure that it will not hinder the primary goal of constructing the building or spoil the final form of the building. (Košir et al., 2018).

Architects work hand-in-hand with other

professionals such as civil and HVAC engineers to deliver qualified designs. Architects have several responsibilities during all stages of a project, from the initial drafts and meetings to the inauguration of a building. Architects are appointed by the client, and they have the duty of gathering all the information and ideas necessary to create a functional space that meets client needs while being code compliant (Martini et al., 2014).

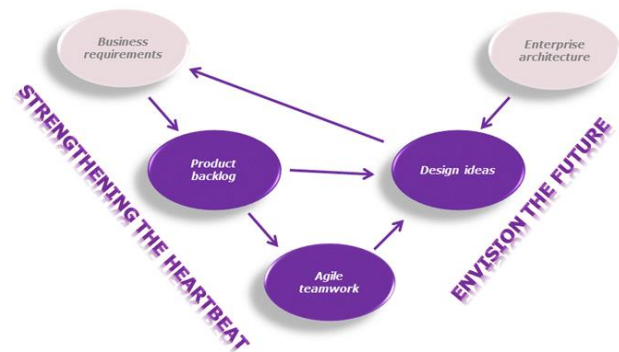


Figure 2: The role of architects- Source (Košir, Gostiša, & Kristl, 2018)

1.3 Architect Skills and Duties:

The following are some of the main skills that a professional architect must have (Martini et al., 2014):

- **Customer service and retention:** Architects must have communication skills and how to present the design idea to the customer in a clear way, and keep customers in contact and knowledge in all the uses of the projects while meeting all the needs of users within the designed projects
- **Design:** Architects must design, plan and develop design ideas based on the requirements and needs of clients
- **Research:** Architects must learn about different building codes, safety regulations and building innovations so as to develop their designs to be compatible with the development in society.



Figure 3: Architect Skills and Duties. Source (Martini, Pareto, & Bosch, 2014)

Technological knowledge: Architects must be trained in software and modeling techniques,

such as BIM, to keep pace with technological development, especially in the areas of software

and its impact on building construction processes to increase implementation accuracy and save money, time and effort.

2. The golden ratio:

The golden ratio is also called the golden mean or golden section (Latin: sectio aurea), other names include extreme and mean ratio, medial section, divine proportion, divine section (Latin: sectio divina), golden proportion, golden cut, and golden number(Jozsef, 2016).

Through some studies, it is believed that the golden ratio was used in ancient civilizations, especially Egyptian and Greek architecture, for example the design and construction of the Great Pyramid (Khufu) in the ancient Egyptian civilization, as well as the Parthenon temple in the Greek civilization.(Meisner, 2016).

Mathematics geniuses such as Euclid and Pythagoras of ancient Greek civilization, passing through the medieval Italian mathematician Leonardo of Pisa who created the Fibonacci sequence based on the achievement of the principles of the golden proportions and the Renaissance astronomer Johannes Kepler, paid attention to current scientific figures such as the Oxford physicist Roger Penrose, they spent years of their life to study the properties of the golden ratio and its applications in nature, but the fascination with the golden ratio is not limited to mathematicians only. Saying that the golden ratio has inspired thinkers from all disciplines as much as any other number in the

history of mathematics.(geographic, 2021, October 25).

The ancient Greeks realized the property of the "Section" and came up with the golden section, after more than 2,000 years, the "The Section of The ancient Greeks" was classified as "golden" by the German mathematician Martin Ohm in 1835, the Greeks noted that the use of the rectangle provides the most golden ratio, This thought dominated architects during the Renaissance, for example, through the work of the Italian polymath Leonardo da Vinci and the publication of the De divina ratio, written by Italian mathematician Luca Pacioli and drawn by Leonardo.(Bogomolny & Puzzles, 2017).

The golden ratio is an irrational number that contains an infinite number of digits after the decimal point and is approximately equal to 1.61803398.....

In an equation form, it looks like: $a/b = (a+b)/a = 1.6180339887498948..$

Where the golden ratio is represented mathematically by the irrational number $(1 + \text{square root of } \sqrt{5}) / 2$, denoted by the Greek letter Φ , where it is approximately equal to 1.618, is the ratio of a straight section cut into two pieces of different lengths so that the ratio of the entire section to the longest one is equal For the ratio of the longest segment to the shorter segment(Bogomolny & Puzzles, 2017).



The golden ratio is also represented by the following mathematical formula, where the variables x and $y \geq 0$, where the ratio between the largest variable (x) to the smallest (y) is equal to the ratio between the sum of the two variables (x, y) to the largest variable (x) is equal to the golden ratio = 1.168.

$$\frac{x}{y} = \frac{x + y}{x}$$

2.1 The Fibonacci sequence:

Leonardo Bonacci or Leonardo of Pisa (1170-1250) was an Italian mathematician from the Republic of Pisa, who discovered a sequence now known as the Fibonacci sequence that approximated the golden ratio, Fibonacci sequence is “a sequence of numbers in which each number is the sum of the previous two numbers: 1, 1, 2, 3, 5, 8, etc. (Benavoli et al., 2009).

The Fibonacci sequence can be represented in the following simplified mathematical formula, which is the value of the simplest continuous fractions, which is $1 + 1 / (1 + 1 / (1 + 1 / (1 +$

...(Benavoli et al., 2009).

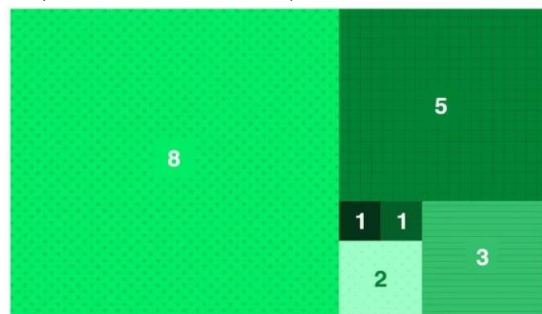


Figure 4: the series of Fibonacci sequence 1, 1, 2, 3, 5, 8, 13... Source: (Benavoli et al., 2009)

The relationship of the golden ratio with the Fibonacci sequence can be found by dividing each number by the one before it. (Benavoli et al., 2009):

- 1/1=1
- 2/1=2
- 3/2=1.5
- 5/3 = 1.666
- 13/8 = 1.625
- 21/13=1.615

The further you go in the series of Fibonacci

sequence the closer you get to the golden ratio, for example: $377/233 = 1.61805$.

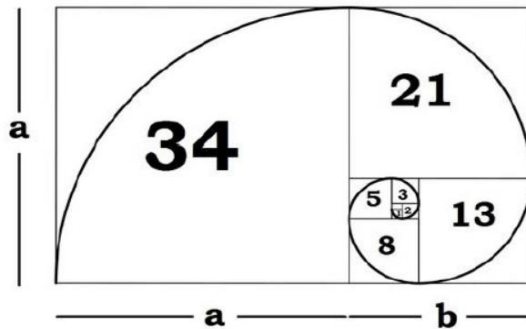
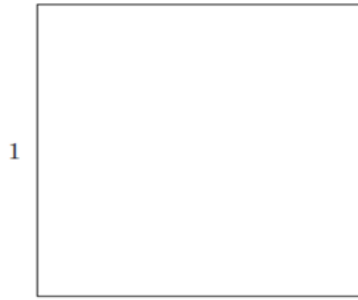
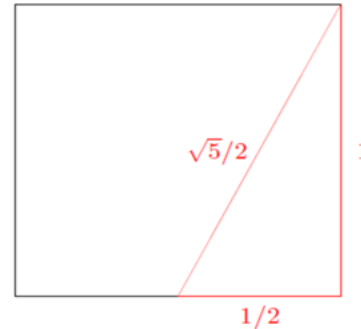


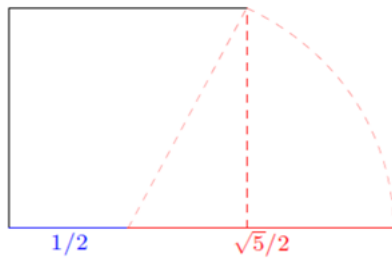
Figure 5: The simplest is the series of Fibonacci



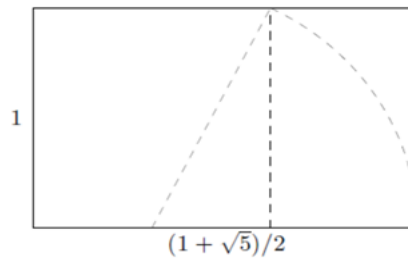
1. Draw a Square.



2. Draw a diagonal line from midpoint to corner.



4. Complete the golden rectangle.



Draw an arc using the internal line as radius.

Figure 6: Classical construction of the golden rectangle. Source: (Livio, 2008)

Where $\Phi = x/y$ refers to golden ratio, (Φ) is the capital Greek letter Phi, the equation becomes,

$$\Phi = 1 + \frac{1}{\Phi},$$

Or equivalently Φ is the positive root of the quadratic equation:

$$\Phi^2 - \Phi - 1 = 0.$$

The result of applying the quadratic formula is:

$$\Phi = \frac{\sqrt{5} + 1}{2} \approx 1.618.$$

The negative root of the quadratic equation represents the conjugate golden ratio and is called ϕ in relation to the lowercase Greek letter phi and is represented by the following equation:

$$\phi = \frac{\sqrt{5} - 1}{2} \approx 0.618.$$

The relationship between the golden ratio

sequence 1, 1, 2, 3, 5, 8, etc. Source: (Benavoli et al., 2009)

2.2 The golden rectangle:

The golden rectangle is a rectangle of ratio between its sides that represents the golden ratio, where the golden rectangle is represented by drawing a square and then drawing a line from the midpoint on one side to the corner of the opposite side, then drawing an arc from the corner to the length of the side with the midpoint (Livio, 2008).

Finally, the golden rectangle is completed as shown in Figure 6.

conjugate ϕ and the golden ratio Φ , is given by (Livio, 2008):

$$\phi = \Phi - 1,$$

or using,

$$\phi = \frac{1}{\Phi}.$$

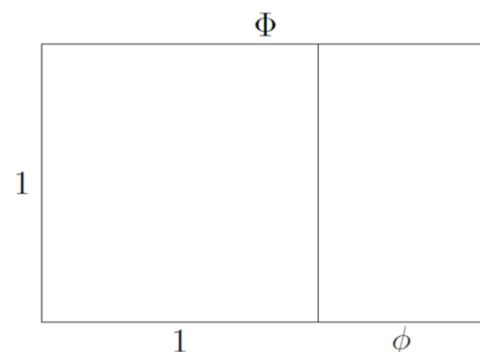


Figure 7: The relationship between the golden ratio conjugate ϕ and the golden ratio Φ .

Source: (Livio, 2008)

2.3 Spiraling squares:

Spiraling squares: the full rectangle and the adjacent rectangle are both golden rectangles where the side is increased by the mathematical equation $\phi = \Phi - 1 = 1/\Phi$, to create a golden rectangle of length $L = \Phi$ and width $W = 1$, a smaller rectangle is attached to the unit square as shown in the figure 8. The smaller rectangle has a vertical length $L = 1$ and a horizontal width $W = \Phi - 1$, but since $\Phi - 1 = 1/\Phi$, the smaller rectangle satisfies $\Phi = L/W$, so it is also a golden rectangle (Hashemiparast & Hashemiparast, 2011).

This smaller golden rectangle can be divided again into a smaller square and a golden rectangle, and this process can continue infinitely, since in each subsection the length of the square is reduced by a factor of $\phi = 1/\Phi$.

Subdivisions can be done either counterclockwise or clockwise, since in a clockwise direction, the square is placed first on the left, then up, then right, then down the rectangle, and so on.

In the end, we get Figure 8, where the lengths of the sides of some squares in their centers are written as powers of ϕ .

Finally, a golden rectangle can be obtained as shown in Figure 8, since it is a miniature version of the whole, and things that contain miniature copies of it are called similar.

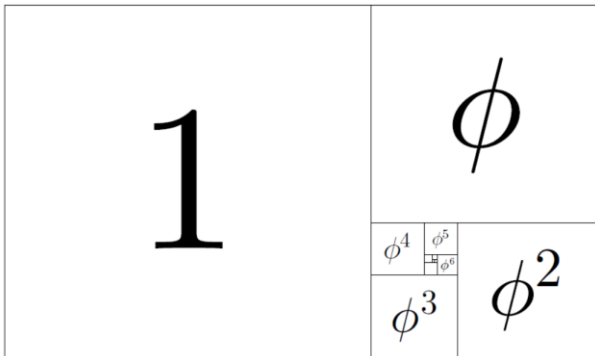


Figure 8: Spiraling squares. Source: (Hashemiparast & Hashemiparast, 2011).

2.4 The golden spiral:

The golden spiral is a special case of a logarithmic spiral of radius r which can be formulated by the mathematical equation:(Benavoli et al., 2009)

$$r = ae^{b\theta}$$

where θ is the usual polar angle, and a & b are constant values, since Jacob Bernoulli (1655-1705) carefully studied this spiral and gave it the name spira mirabilis, or miracle spiral, then recommended that it be drawn on his tombstone with the inscription “Eadem mutata resurgo”.

Since the golden spiral is a logarithmic spiral whose radius increases or decreases by a factor of the golden ratio Φ with each quarter of a turn, that is, when it increases by $\pi/2$, where the golden spiral can be represented by the following mathematical equation:

$$r = a\Phi^{2\theta/\pi}$$

The spiral can be formed inside the golden rectangle, the size of each successive square decreases by a factor of Φ , with four squares that make up each full turn of the spiral, then we put the center point of the spiral at the point of intersection of all squares, and fit the modulus a so that the golden spiral passes through the corresponding corners of the squares, then the Beautiful golden spiral shows as a result, as shown in Figures 9-10-11.

2.5 The golden angle:

The sunflower is represented as a reference from nature to measure the golden angles, where the golden angle is defined as the acute angle g that divides the circumference of the circle into arcs with a length in the golden ratio (see Figure 12) (Benavoli et al., 2009).

The golden ratio Φ and the golden ratio conjugate ϕ satisfy:

$$\Phi = \frac{x}{y}, \quad \phi = \frac{y}{x'}$$

With $\Phi = 1 + \phi$. We can determine the golden angle by writing

$$\begin{aligned} \frac{g}{2\pi} &= \frac{y}{x+y} = \frac{\phi}{1+\phi} \\ &= \frac{\phi}{\Phi} = \phi^2; \end{aligned}$$

And since $\phi^2 = 1 - \phi$, we obtain

$$g = 2\pi(1 - \phi).$$

Expressed in degrees, this is $g \approx 137.5^\circ$.

2.6 The Golden pyramid and triangle:

Where recent studies have shown that the Great Pyramid of Khufu is subject to the laws of the golden ratio, as the ratio between the distance from the top of the pyramid to the middle of one of the sides of the face of the pyramid, and the distance from the same point to the center of the square base of the pyramid is equal to the golden ratio. Herodotus referred to the proportions in the pyramid He said: “The Egyptian priests told me that the proportions established in the Great Pyramid between the side of the base and the height allowed that the square built on the height equal

exactly the area of each of the triangular faces of the pyramid." It is also indicated that the king's chamber in the pyramid of Khufu achieved the golden ratio.

A regular square pyramid is determined by its medial right triangle, the edges of which are the shape of the pyramid (a), the semi-base (b), and the height (h); the angle of inclination of the face is also marked. Mathematical proportions B: H: A from 1:: Φ and 3: 4: 5 and 1: 4 /: 1.61899(Akhtaruzzaman et al., 2011).

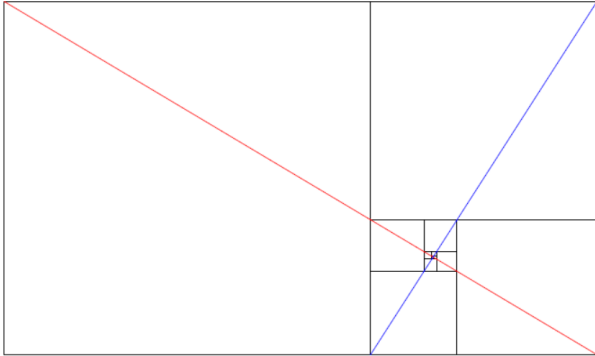


Figure 9: The center of the golden rectangles and the golden spiral. Source: (Benavoli et al., 2009)

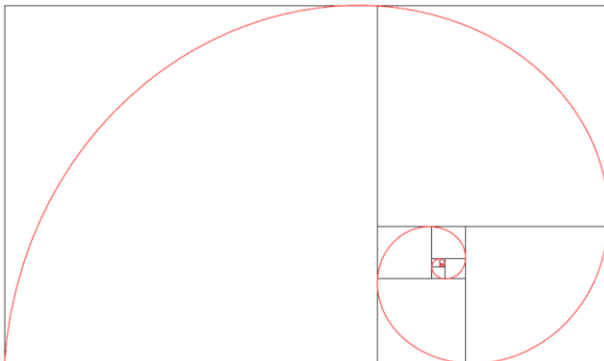


Figure 10: The central point of the golden spiral. Source: (Benavoli, Chisci, & Farina, 2009)

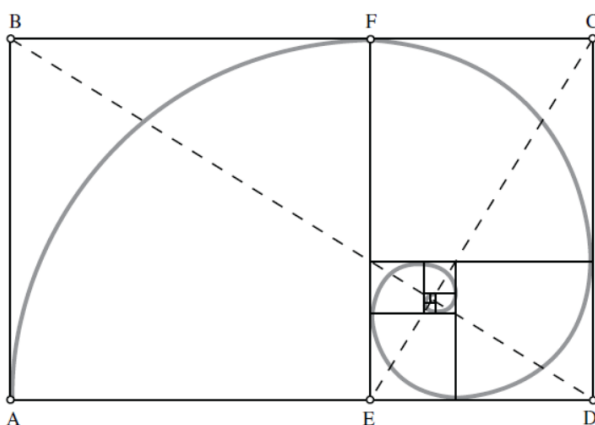


Figure 11: Spiral center and Golden Rectangles $AE = AB = 1$, $AD = \Phi$, $FC(\emptyset) = \Phi - 1 = 1/\Phi$. Source: (Benavoli et al., 2009)

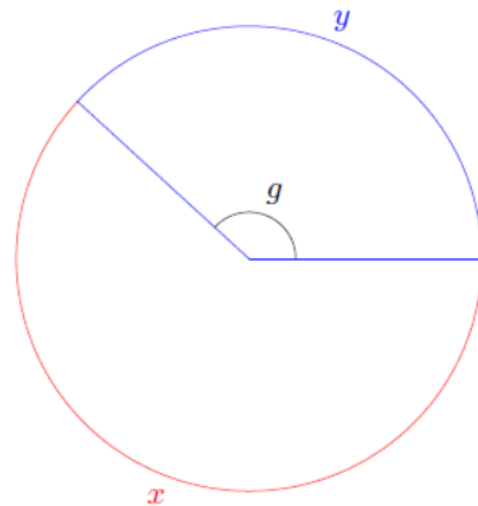


Figure 12: The golden angle g. Source: (Benavoli et al., 2009)

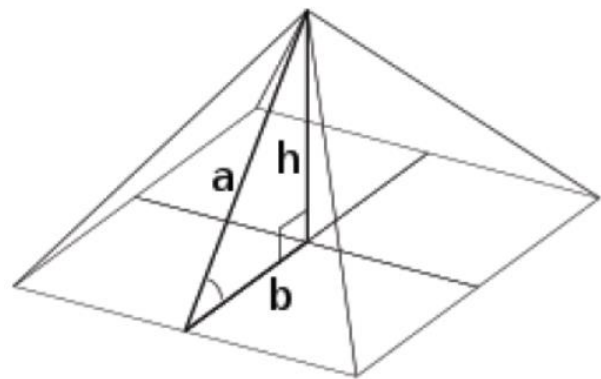


Figure 13: The golden pyramid and triangle. Source (Akhtaruzzaman et al., 2011)

2.7 Golden ratio (Fibonacci sequence) in nature:

Through studies that focused on the applications of golden ratios and successive Fibonacci in nature, he found, for example, the sunflower shown in Figure 14, and noticed the spirals visible in the florets that radiate from the center to the edge, where we find that these spirals rotate in a clockwise direction and others in the counterclockwise.

By counting them, he found that 34 spirals are counterclockwise and 21 spirals are clockwise.

Surprisingly, the numbers 34 and 21 are Fibonacci sequence (Jozsef, 2016).

The pinecone from the top, your eye will pick up spirals, there are actually two sets of spirals in this picture: 13 clockwise and 8 counterclockwise (Jozsef, 2016).

2.8 Applications of golden ratio in Architectural:

2.8.1 Ancient Egypt:

In front of the studies that were carried out on the applications of the golden proportions in the field of architecture, especially ancient civilizations, it was found that one of the most important achievements of the ancient Egyptian civilization was the pyramid of Khufu, which came remarkably close to the "golden pyramid", as it was found that

its slope of 51 degrees 52' is very close to the slope of the "golden pyramid" At 51 degrees 50 degrees and the inclination of the pyramid based on pi is at 51 degrees similarly we find that the other pyramids at Giza are also very close to the golden ratio 3:4:5, but these studies remain uncertain whether the relationship with the golden ratio in these Pyramids by design or by chance.(Jozsef, 2016).

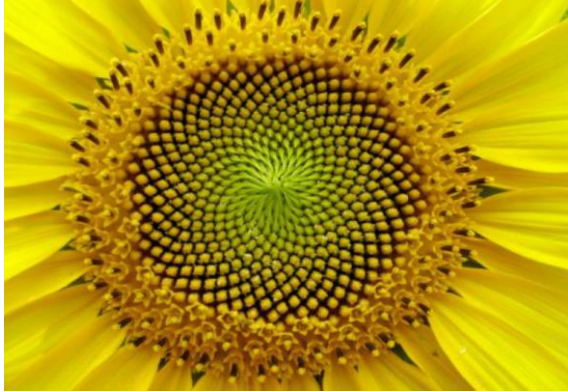


Figure 14: The flowering head of a sunflower.
Source: (Jozsef, 2016)

In 1859, John Taylor of pyramid science claimed that in the Great Pyramid the diagonal aspect ratio of the pyramid can be measured to half the height. The base length is 612.01 (ft.) / 377.9 (ft.) = 1.6195 is the golden ratio(geographic, 2021, October 25).

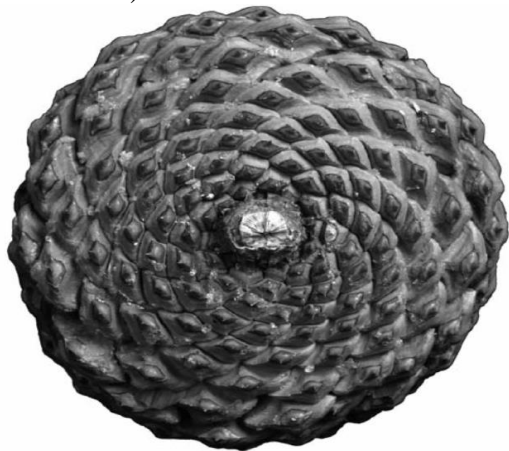


Figure 15: A pinecone viewed from the top. Source: (Jozsef, 2016)

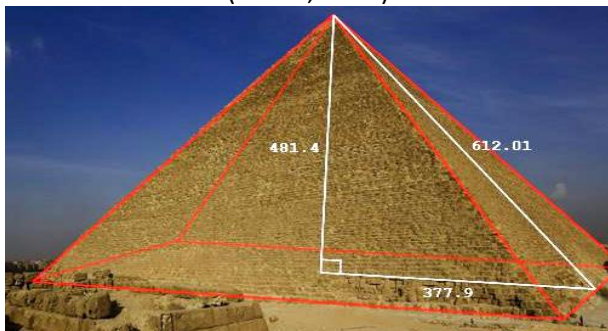


Figure 16: The Great Pyramid of Giza, Egypt.
Source: (Jozsef, 2016)



Figure 17: The Epidaurus Theater. Source: (Bogomolny & Puzzles, 2017)

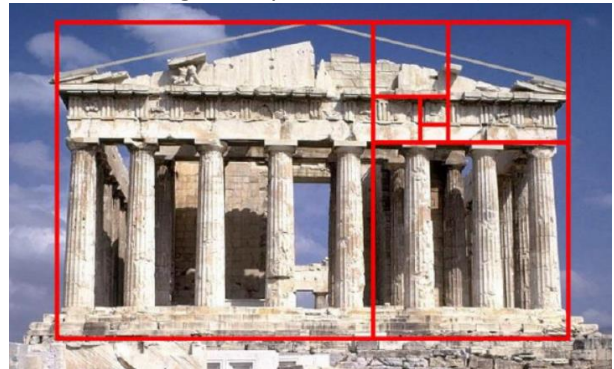


Figure 18: The famous Greek temple, the Parthenon. Source: (Bogomolny & Puzzles, 2017)

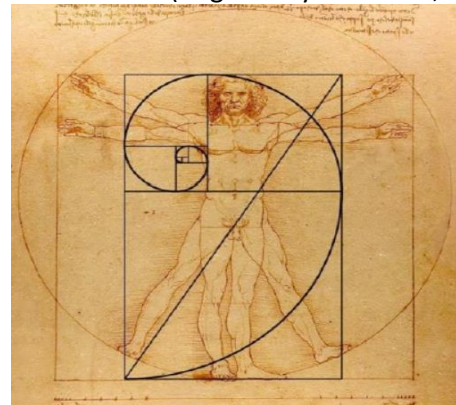


Figure 19: The Vitruvian Man by Leonardo da Vinci and a Golden Mean drawing. Source: (Foutakis, 2014)

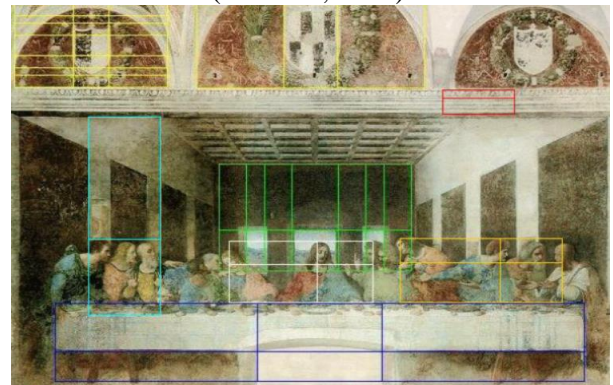


Figure 20: The Last Supper by Leonardo da Vinci and a Golden Mean drawing. Source: (Foutakis, 2014)

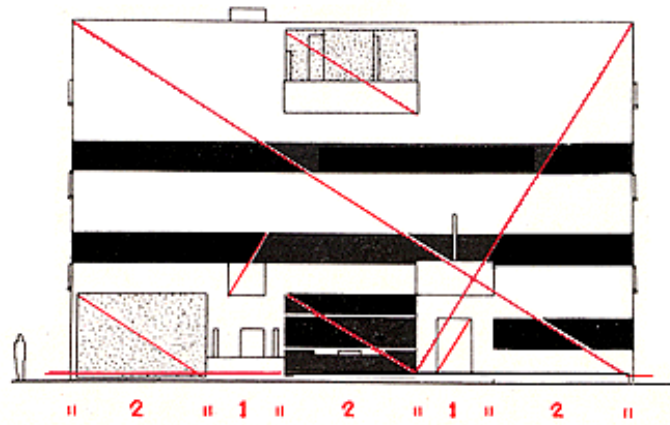


Figure 21: Le Corbusier's Stein Villa in Garches-1927. Source: (Jozsef, 2016)

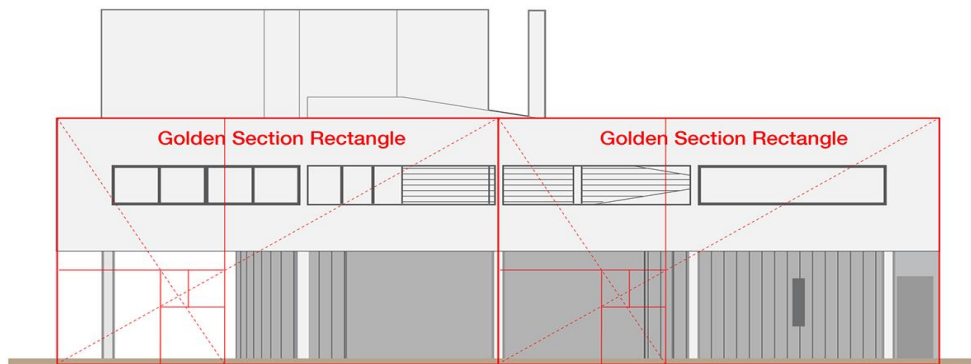


Figure 22: Le Corbusier's Villa Savoy. Source: (Jozsef, 2016)

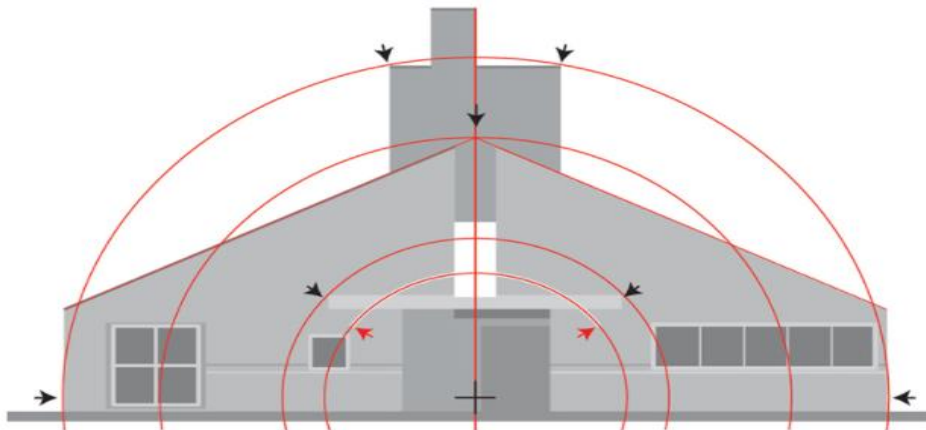


Figure 23: Robert Venturi's Vanna House . Source: (Jozsef, 2016)

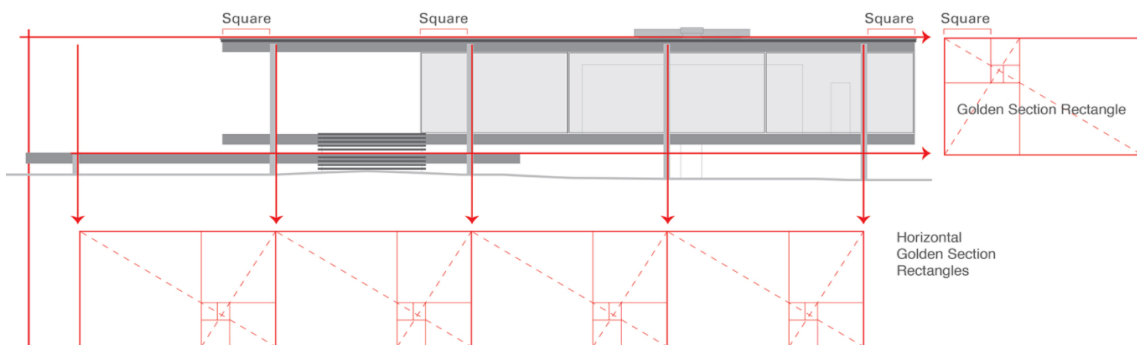


Figure 24: van der Rohe's Farnsworth House. Source: (Jozsef, 2016)

The Swiss architect, Le Corbusier, is considered one of the most important architects of the modern era, who applied the golden proportions to his architectural works, as his design

philosophy is based on systems of harmony and proportion. Le Corbusier's belief in the mathematical order of the universe was closely related to the golden ratio and the Fibonacci

sequence, which he described as "rhythms visible to the eye and evident in their relations to each other"(Foutakis, 2014).

Le Corbusier explicitly used the golden ratio in his standard system of the architectural ratio scale. He saw this system as a continuation of a long tradition of Vitruvius, influenced by Leonardo da Vinci's "Vitruvian Man", the work of Leon Battista Alberti, and others who used the proportions of the human body to improve the appearance and function of architecture as well as the golden ratio, so Le Corbusier built a grid system on the measurements Humanity for the painting "Vitruvian Man" and Fibonacci numbers, where he made a modeling of the human body and divided it into two parts at the navel and then divided these sections in a golden ratio at the knees and throat in order to achieve balance and harmony in his work and called this system "Le Corbusier modular system"(Jozsef, 2016).

One of the most important examples of the application of Le Corbusier's modular system Villa Stein Le Corbusier in 1927 in Garches and Le Corbusier's Villa Savoy where the rectangular ground plan of the villa, the height and the internal structure are very close to the golden rectangle.

Also among the most important architectural works that applied the golden ratio are the house of Robert Venturi Vanna and the house of Mies van der Rohe in Farnsworth.

The CN Tower in Toronto was built in 1974, as it represents a model for buildings in which the principle of the golden ratio was established in perspective, as the height of the tallest tower in the world is 553.33 meters, and the height of the glass floor is 342 meters, where the ratio of these two values is equal to 1.617924, which represents the golden ratio(Jozsef, 2016).



Figure 25: CN Tower in Toronto, Ontario, Canada.
Source: (Jozsef, 2016)

2.8.2 Ancient Greece:

An example of the application of the golden ratios in the Greek civilization is the Epidaurus Theater, which was designed by Polykleitos the Younger in the fourth century BC and represents a model of the Greek theaters in which the golden ratio was used, where the hall was divided into two parts, one of which contains 34 rows and the other 21 rows (Fibonacci sequence), and the value of the angle between the theatre and the stage divides a circumference of the basis of an amphitheatre in the ratio $137^{\circ}.5 : 222^{\circ}.5 = 0.618$ (the golden ratio).(Bogomolny & Puzzles, 2017).

One of the most important examples of applying the golden ratios in the ancient Greek civilization is the Parthenon Temple, where many Greek mathematicians, artists and philosophers used the golden ratio, the golden ratio was also named Phi referring to Phidias (500 BC - 432 BC)(Bogomolny & Puzzles, 2017).

2.8.3 Modern architecture:

One of the most important examples of the application of golden ratios in art is the painting The Last Supper of Leonardo da Vinci, where he used the golden ratio in this painting to determine the basic parts of the painting, and to rationalize the proportions of the body such as the proportions of the wall. In 1509 Luca Pacioli published a treatise De Divina Proportione, which contains illustrations by Leonardo da Vinci, a painting of Vitruvian Man in which he called the "Oath of Aurea", the Latin name for the golden ratio, and by several Renaissance artists. The golden ratio is used in paintings and sculptures to achieve balance(Foutakis, 2014).

3. Golden ratio of Architecture Modular system:

Through the study of the Fibonacci sequence 1, 2, 3, 5, 8, 13, 21,, and the research reached the establishment of an architectural module based on the Fibonacci sequence to help architects access the golden ratio spaces in the plan drawings is as close as possible.

Through experimental attempts, the research found that the best architectural module that achieves the Fibonacci sequence in order to reach the golden ratios is 1, 2, 2, 1, 2, 2, 1,, and so on in the axial direction X, Y As shown in Figure 26.

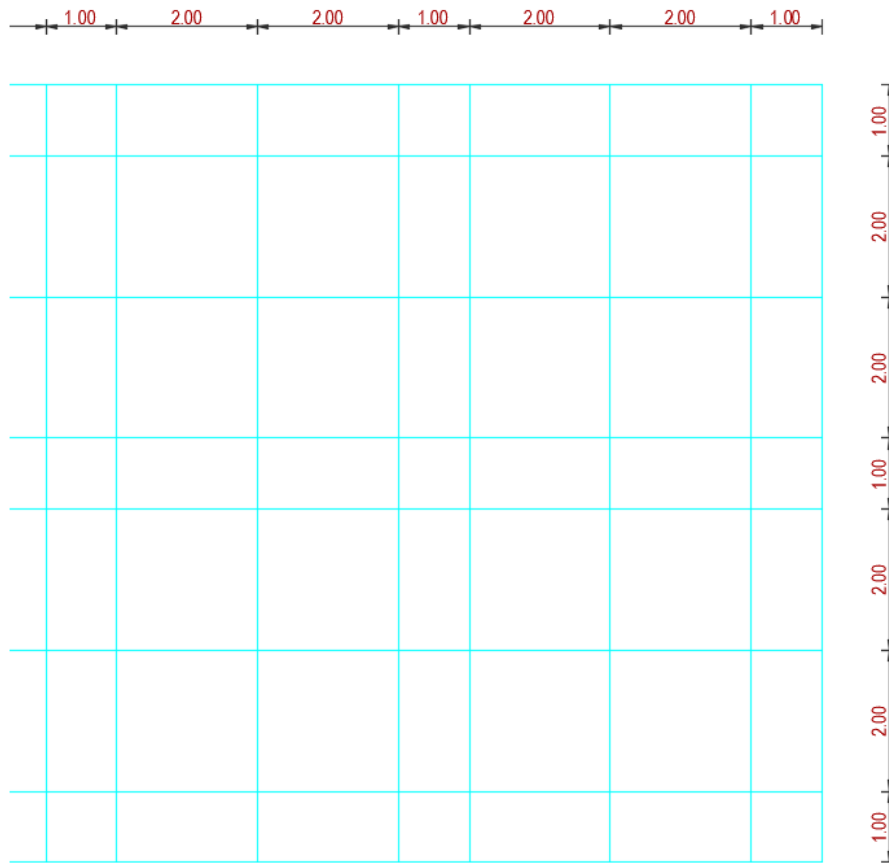


Figure 26: Proposed Architectural Module. Source: The researcher

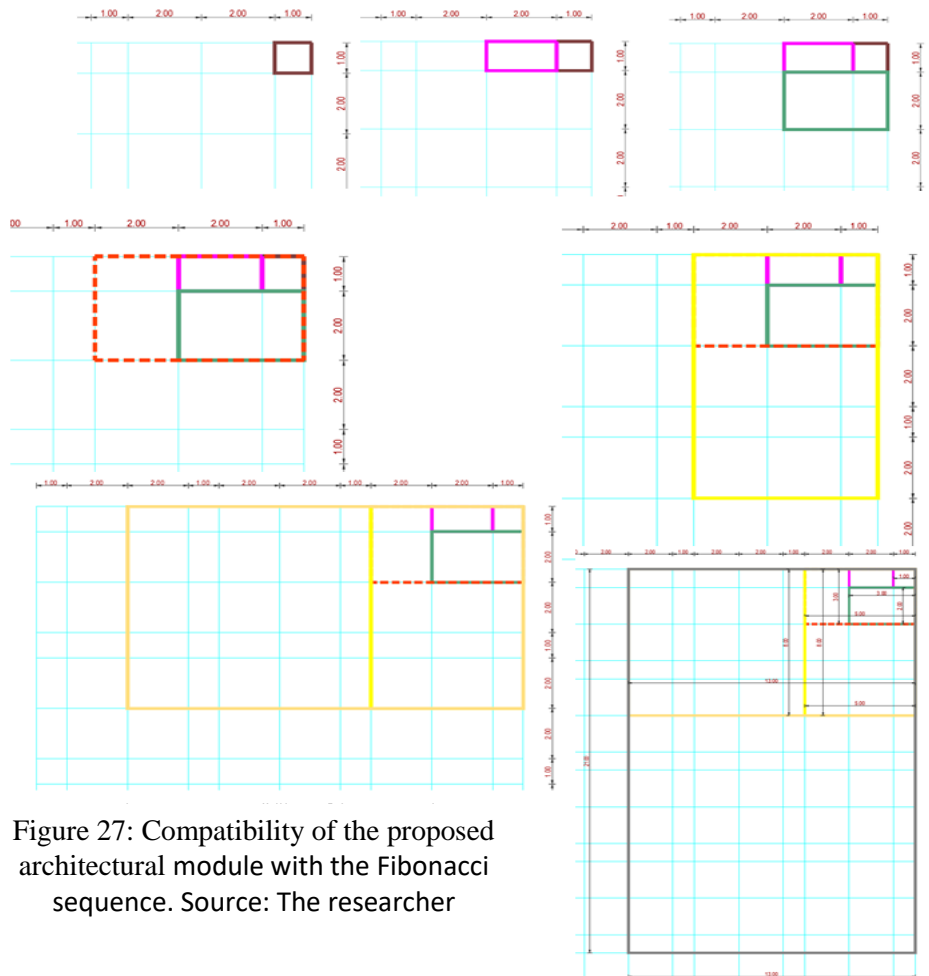


Figure 27: Compatibility of the proposed architectural module with the Fibonacci sequence. Source: The researcher

The Fibonacci sequence was tested on the proposed architectural module by drawing rectangles that follow the Fibonacci sequence. It started with the square shape with dimensions of 1 * 1 and is considered the basis for launching the Fibonacci sequence as mentioned previously in the theoretical study in the research, then draw the figure with dimensions of 1 * 2, then follow the figure 2 * 3 then 3 * 5, then 5 * 8, then 8 * 13, Then finally draw a rectangle with dimensions 13 * 21.

The proposed architectural module corresponds to the geometric shapes that follow the Fibonacci sequence and achieve the golden ratio by dividing both sides of the geometric figure from the beginning of the ratios 3: 5 and so on until we approach the golden ratio 1.16 as shown in

Diagram No.28

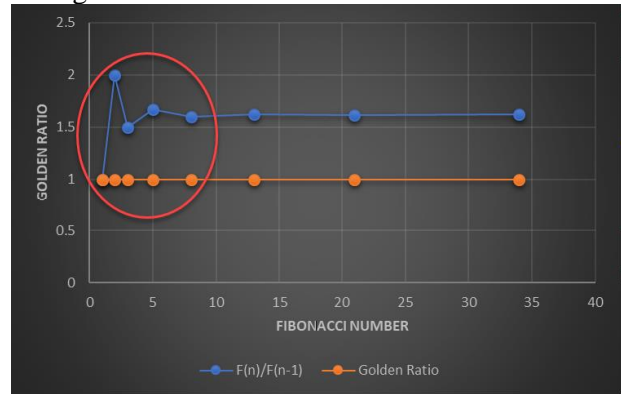


Figure 28: The relationship between golden ratio and Fibonacci sequence.

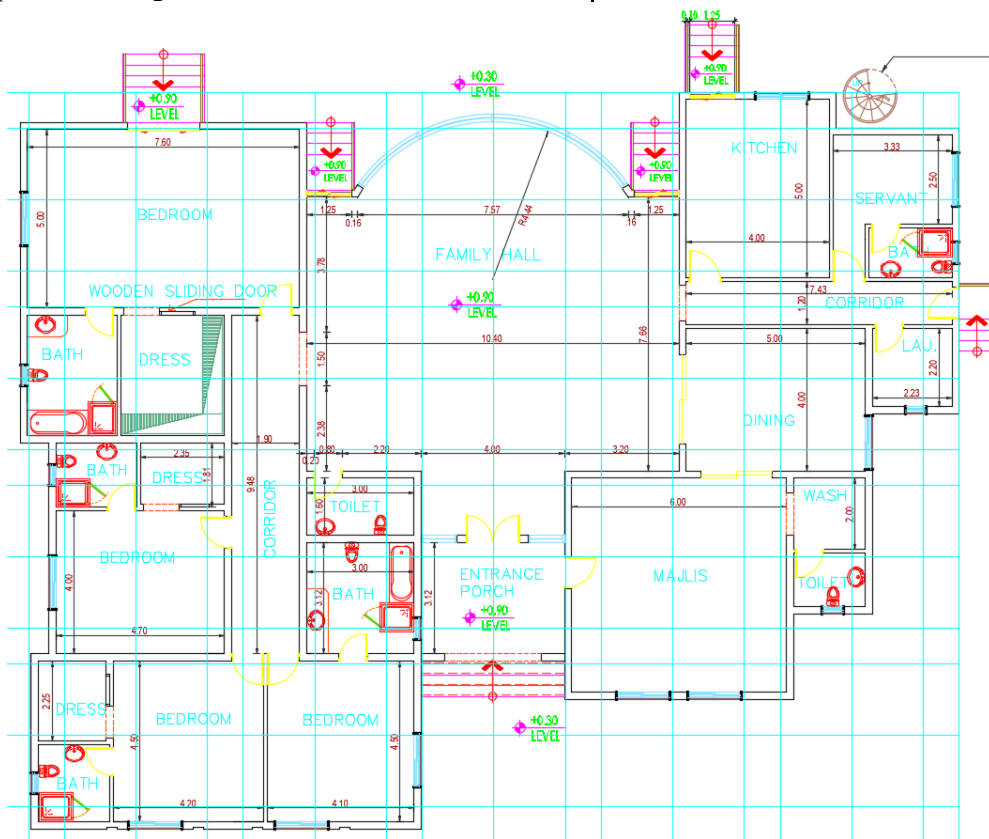


Figure 29: Existing residential villa before modifications. Source: The researcher

design and respecting the boundaries of the architectural spaces of the proposed architectural module as shown in Figure 30.

Results:

- Research finds that the proposed technique, represented in the proposed architectural module, reshaped the architectural spaces, making it approach the golden ratios without changing the functional design criteria.
- Research that the proposed architectural module is characterized by high flexibility, which helps the architect's creativity in design.
- The proposed architectural module helped to

4. Application of the proposed architectural module on a residential villa:

An architectural design was used for an existing residential villa, where the proposed architectural module was applied to the plan of the horizontal plan of the existing villa, as in Figure 29, where it was found that the designed architectural spaces do not follow the golden ratios in the geometrical shape of the space through the length and width of the architectural space and also found wasted spaces .

The architectural design of the existing residential villa was modified in accordance with the proposed architectural module, by modifying the

ensures human comfort for the user within the architectural space.

- Research find that the application of the proposed architectural module will help to reduce wasted spaces and thus reduce construction costs and thus reduce the rate of environmental pollution and achieve the concept of sustainability.

Recommendations

- Encouraging architects to apply the proposed architectural module to ensure that the golden ratios are achieved to form architectural spaces for the convenience of users, reduce wasted spaces, and comply with construction systems.

organize the architectural spaces and reduce the wasted spaces in order to ensure the sustainability of the architectural design and reduce the unwanted construction costs.

- The proposed architectural module is compatible with the structural systems, which helps to distribute the columns and structural elements easily and the architectural design does not conflict with the structural design.
- Research find that the Technique made modifications in the dimensions of the architectural spaces of the unit and thus modified the architectural design in a way that does not affect the design idea and achieves the golden ratios for the formation of architectural spaces in the horizontal plane and

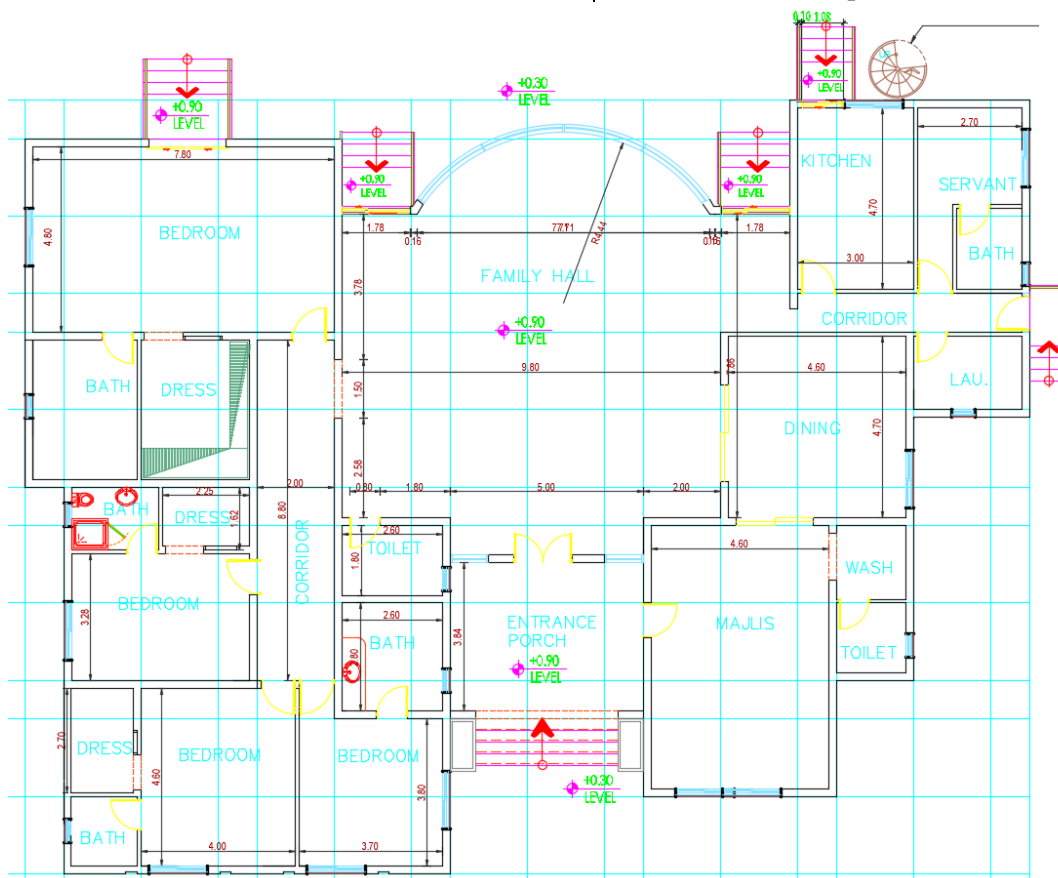


Figure 30: Existing residential villa after modifications. Source: The researcher

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