CHAPTER 6.

RHINOCEROS: A DESIGN TOOL FOR GENERATIVE BIO-DIGITAL AND GENETIC DESIGN – MORPHOGENETIC AND EVOLUTIONARY COMPUTATION

An introduction to the used program and its plugins then a case study of Morphogenetic and Evolutionary Computational Design (Bio-digital and Genetics) using Rhino Script program with its plugins (Grasshopper – Galapagos – GECO) is introduced.

Keywords:

PLUGINS – RHINOCEROS – GALAPAGOS – GRASSHOPPER- GECO – ECOTECT – HOUSING PROPOSAL – SOFTWARE INTERFACE

CHAPTER SIX

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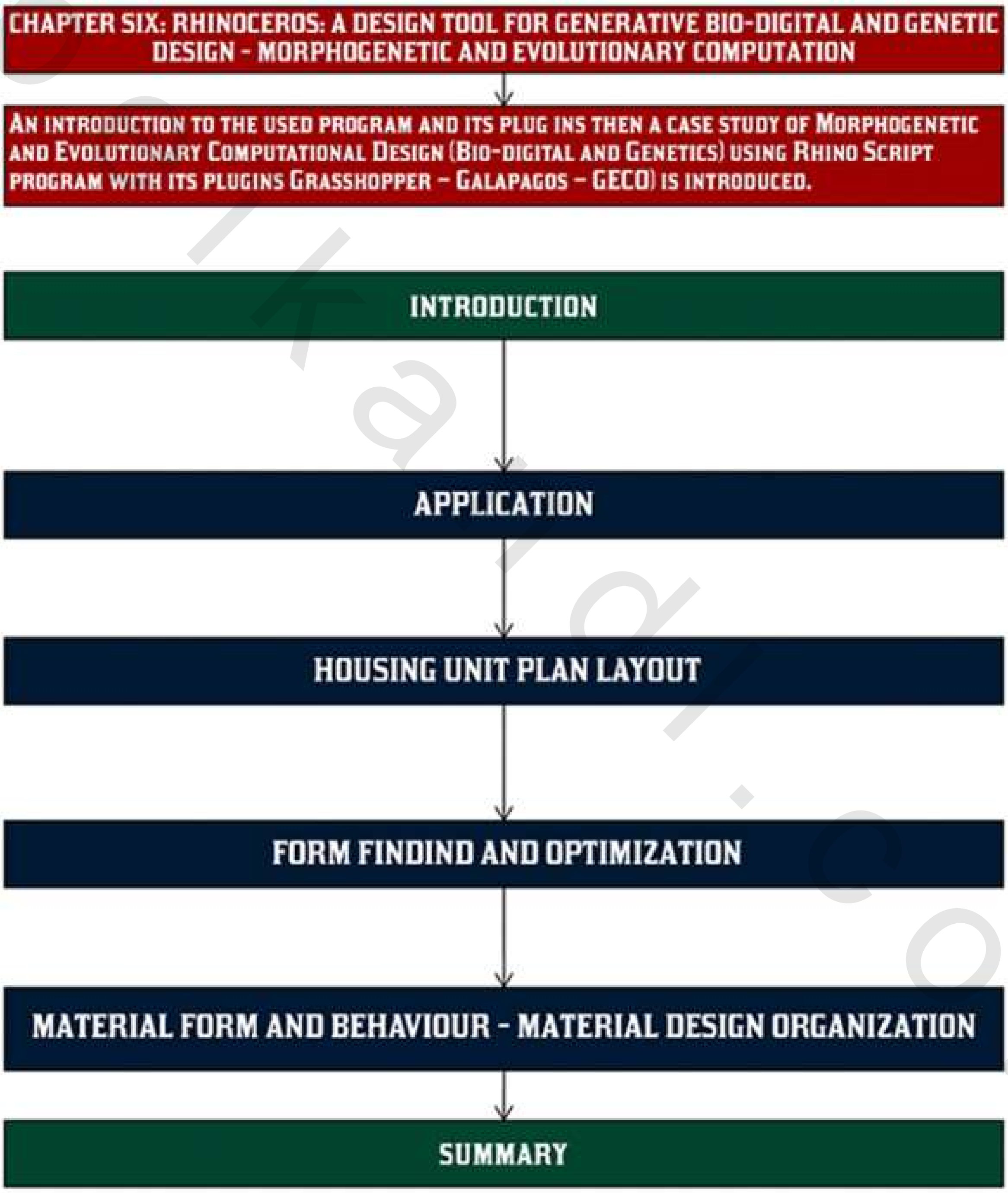
CHAPTER STRUCTURE: APPLICABLE SECTION



6.1. APPLICATION:

6.1.1. Introduction:

As the government is looking forward to construct new housing (residential) units all over the country, which aims to solve the over population in big cities and providing new units for those living in non-homogenous spaces or for youth searching for new places to start their new life. This research aims to apply an evolutionary morphogenetic computational design process to get a residential unit proposal and a bio-digital design module proposal synthesis to environmental changes and nature. Where this evolutionary design process steps can be a design tool to generate and find a cluster, building, zone, layout plan ...etc.

The evolutionary design process of bio-digital design and genetics can be one of the best designing processes in finding form; especially if it is needed to find a morphogenetic computational form responding to nature and environmental properties, to get a familiar form corresponding to the ecological surrounding nature.

As presented in the previous chapters many problems can be solved through the uses of evolutionary design and its processes. This morphogenetic and evolutionary computational process in this case study is used to get the best proposal of an architectural plan layout for a residential unit, then changing it to form- form generating a comfortable form for living which differs according to project location due to its surrounding environmental aspects, also the form behavior and material will be genetically optimized and applied on the form, which gets a bio-digital design module proposal syntheses to environmental changes.

Generating this housing proposal needs a computational tool, this tool will be: the Rhinoceros and its plugins Galapagos and Geco, this program is used as an applying platform for morphogenetic and evolutionary computational design, it can be said that: **Rhinoceros applying morphogenesis and evolutionary genetics is a new design tool for form generating. Also this resulting generative system is expected to facilitate the design process, generate unexpected solutions for well specified rules and save time consumption for the architects in the early design process. For program details and interface see appendix 1.**

A case study subject of a generative model of a house created of bio-digital and genetic process through design with different optimization points through formation and materialization. Rhinoceros and its plugins evaluate each house in a population of design variants to determine the amount of heat during its worst-case month affecting its comfort and material, then finding form and applying a suitable material and skin. Individuals requiring the least energy are selected to parent the next generation using deterministic crowding. Architecture is a complex adaptive system where optimization is possible, so an evolutionary design approach should offer useful ideas to the architect, this evaluated populations are generated according to the biological bases used before which can be in this study:

– Adaptation:

It adapt to the needed orientation of the zoning layout, also to the surrounding environment and the solar path according to the site location where the form height changes from one place to another to get the most comfort shaded model with the least penetrating heat and the best ventilation getting the best comfortable interior and adjusting the thermal temperature inside the unit, where it's material opens and close, change its size to provide more shades or ventilation to the interior through its genetic rolling properties.

– Behavior material and environment:

Adjustable material system to form layout behavior and surrounding environment, which open and close give shades and ventilation or preventing sun light

– Emergence:

Emerging of form material and layout through many optimization and generating tools

– Self–organization:

Self-organization of plan layout and material distribution, which is made according to the site location and environmental aspects

– Optimization:

Multi optimization criteria for generating design aims, getting best plan layout and having more suitable layout for other proposals, form finding optimization and material distribution on the chosen form reducing the projected area to sun rays and increasing shaded parts through the height of some zones which shades another, increase and decrease in size to give view and more ventilation, open and close giving more shades or preventing the passage of light and heat.

This case study will progress as a design tool of simulating a morphogenetic and evolutionary computational bio-digital and genetic design solution which will be present on 3 parts as:

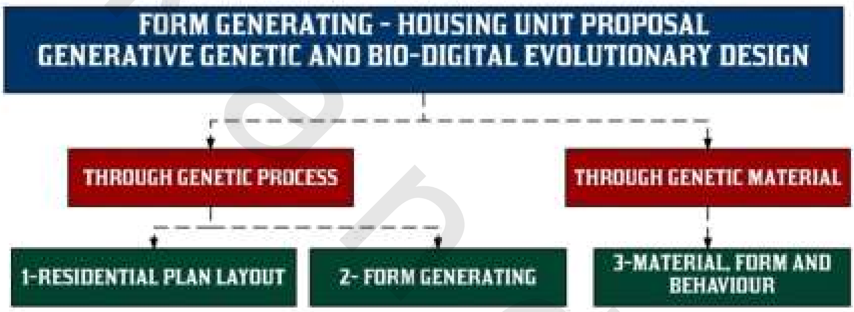


Figure (6- 1): Case study diagram

Source: Researcher 2014

6.1.2. RESIDENTIAL PLAN LAYOUT

6.1.2.1. Case study Genetic Guides: Genotype and Phenotype

The genotype in the optimization procedure is a house built on a 12x12 grid. Each is a square of a four-by-four grid contains a zone, or room, whose parameters with its array column contains many parameters that control its corresponding zone. These include height parameters and the slope of its roof, material parameters, orientation parameter and parameter to control affinity for openings to other zones.

This genotype that encodes the house's parameters is a 4 × 4 × (4-8)m in 9 spaces to find the best orientation for each space according to a given criteria getting the best residential plan layout. The first dimensions of the array correspond to the sides of the twelve-square grid, so that parameters are assigned to each zone getting a best north view. Phenotype in is the 4 directions, sunlight and sun path according to north south east and west with the best view to all zones, which effects the layout design.

Within rhinoceros especially in grasshopper with defining the genotype and phenotype a certain space orientation was stated as following with no overlap in the spaces to fill the 9 zones.

NUMBER OF SPACES	NAME OF SPACE	ORIENTATION	NOTES:THIS IS A RESIDENTIAL UNIT COMPONENTS FILLING A ZONE OF 9 SPACE BLOCKS TO GET THE BEST ARRANGEMENTS
TWO BLOCKS	LIVING SPACE	NORTH / BEST VIEW	
TWO BLOCKS	BEDROOM SPACE	EAST/ NORTH / NORTHEAST	
TWO BLOCKS	TOILET-RESTROOM	SOUTH /SOUTH WEST/ WEST	1 2 3
ONE BLOCK	KITCHEN	SOUTH /SOUTH WEST/ WEST	4 5 6
ONE BLOCK	DINNING SPACE	ANY	7 8 9
ONE BLOCK	ENTRANCE ZONE	SOUTH	

Figure (6- 2): Case study genotype and phenotype
Source: Researcher 2014

These zones are living, dinning, bedroom, toilets, kitchen and entrance lobby as viewed in the previous figure (6-7) with the previous orientation and in relation to the wind direction and client comfort criteria. These spaces were set in a relation to each other viewing the relation between spaces and the direct access between spaces of primary or secondary access in a space diagram which is as following. See figure (6-8)

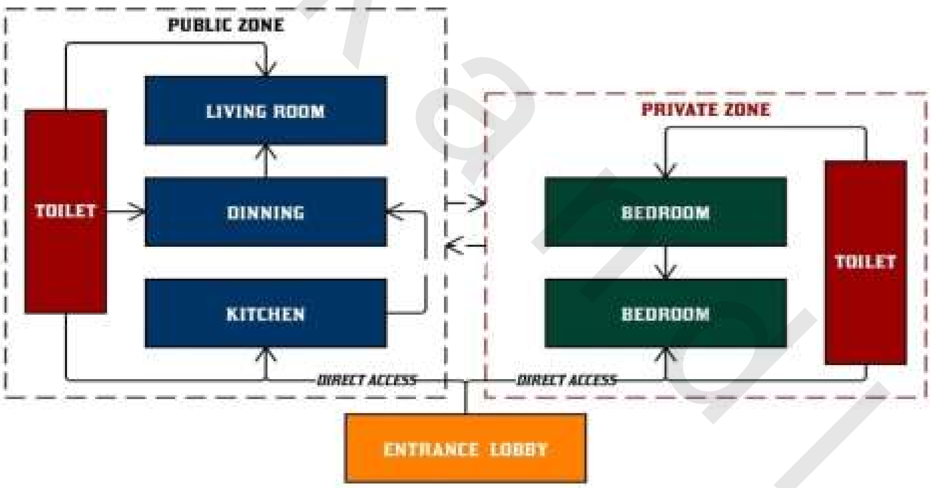


Figure (6- 3): A diagram of the spaces relations which will be built in the rhinoceros
Source: Researcher 2014

6.1.2.2. Final Generated Plan Layout

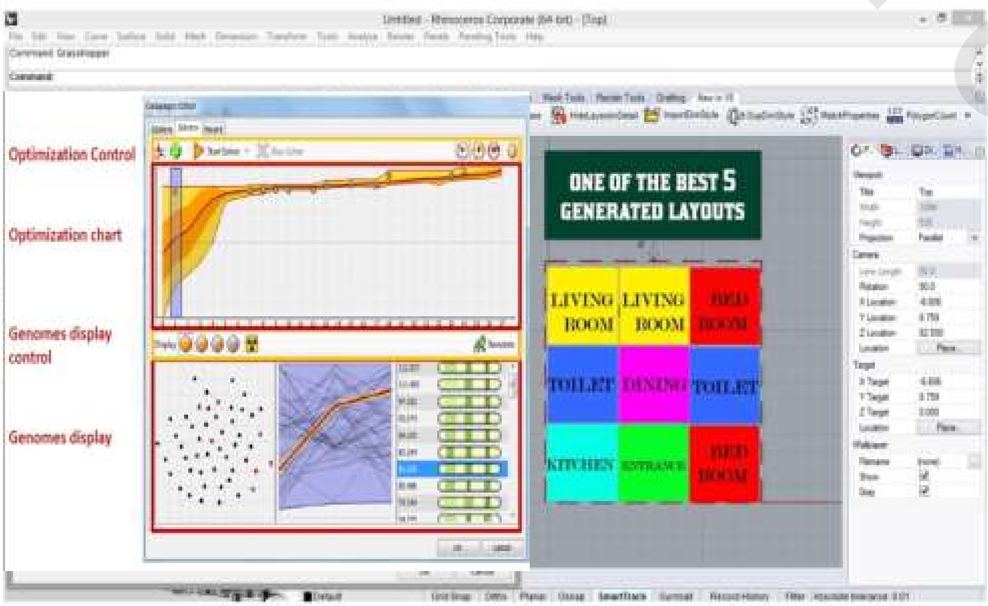


Figure (6- 4): One of the best generated optimized layout organization plans where the architect will edit it to be finalized
Source: Researcher 2014

Many proposals were generated, one of the best 5 proposals is presented as shown in figure (6-9), which shows a double space of living room in the north to get the best view, also a bedroom in the north east and another one in the east, a bath room in the south east serving the private zone, an entrance lobby is in the south and a kitchen in the south west having another guest toilet above it in the west and a dining room in the middle of the zones.

Figure (6- 5): Semifinal architectural plan layout after changing morphogenetic evolutionary computational genetic generated layout into architectural plan to be easily viewed by client.
Source: Researcher 2014

This final result can be achieved, after the designer change it to a suitable architectural plan, see figure (6-10). The generated result can be residential unit or larger design project according to the written inputs, it only need a full information writing bullets for the rhinoceros and grasshopper to generate the best solution, this will be introduced in different cases in the rest of this case study with different input to generate the best output needed.

6.1.3. FORM FINDING – GENERATING FORM

6.1.3.1. Genetic Guides: Genotype and Phenotype

After the plan layout is generated the designer mostly goes to search for the 3d form. This will be introduced also in rhinoceros – grasshopper – Geco – Galapagos as continue to the previously generated architectural residential computational layout case study. This form will be studied in different thermal performance through their presence in different environmental and thermal places in Egypt like Aswan, Cairo and Alexandria where these three of them will be studied.

The genotype and phenotype to generate this form is generated according to the following:

This genotype is extruded from the previously computed layout with a height various between 4 meters and 8 meters with an inclination in the roof points with a minimum of 3 meters height in a point of the 4 points to get the best comfortable shaded zones and to apply the best needed materials to keep the form in its best thermal environmental zone. This will differs from place and thermal zone to another in Egypt effecting the form generation and form material.

The final generated form tended to optimize thermal performance by minimizing their volumes this happens when the phenotype meets an outer environmental and thermal energy. Since the desired volume of a building is generally known very early in design, it was decided to keep the total volume of each 12m × 12 m house constant at 900 m3. Hence, the height parameter actually controls the relative, not absolute, height of the zone. Under this schema, it is possible for a zone to have zero height, in which case Geco ignores it. In zones that do have volume, variation of the two roof slope parameters is limited such that no 2 points in a corner of a zone can be less than 3 m in height.

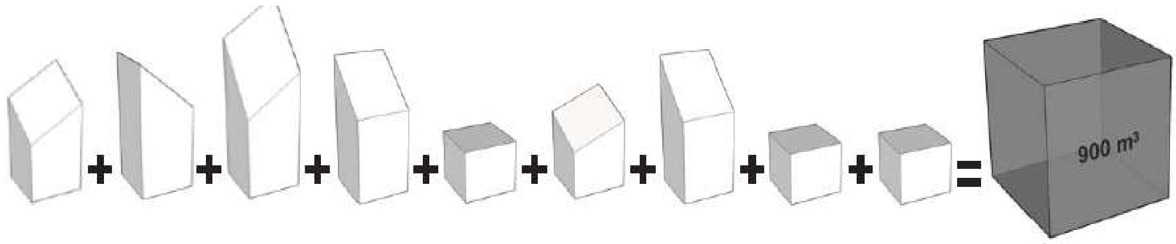


Figure (6- 6): The total volume of the zones is kept constant in order to prevent the program from minimizing the building's volume.
Source: Researcher 2014

6.1.3.2. Variation

• Mutation: A single gene of one parent's 4 × 4 × 4 array genotype is overwritten with a random allele to create an offspring.

• Crossover: The genotypes of two parents are combined to create an offspring. In this case, a random plane described cuts through the array, and genes to one side of the plane are taken from one parent while genes on the other side are taken from the other parent. It is simple to imagine this as phenotypic zones to one side of the plane coming from one parent and zones on the other side coming from the other parent.

• Copy: The parameters for one zone replace those of another zone. Two identical zones appear in the resulting offspring's phenotype, while the same zone appears only once in the parent.

• Rotate: The parameters for one zone's roof slope and wall material assignments are reordered in such a way that the phenotypic zone in the offspring appears to have rotated 90° from its orientation in the parent. When this variation operator is called, it executes one, two, or three times, so that rotations of 90°, 180°, or 270° are equally likely. Only one variation operator is used to create each offspring.

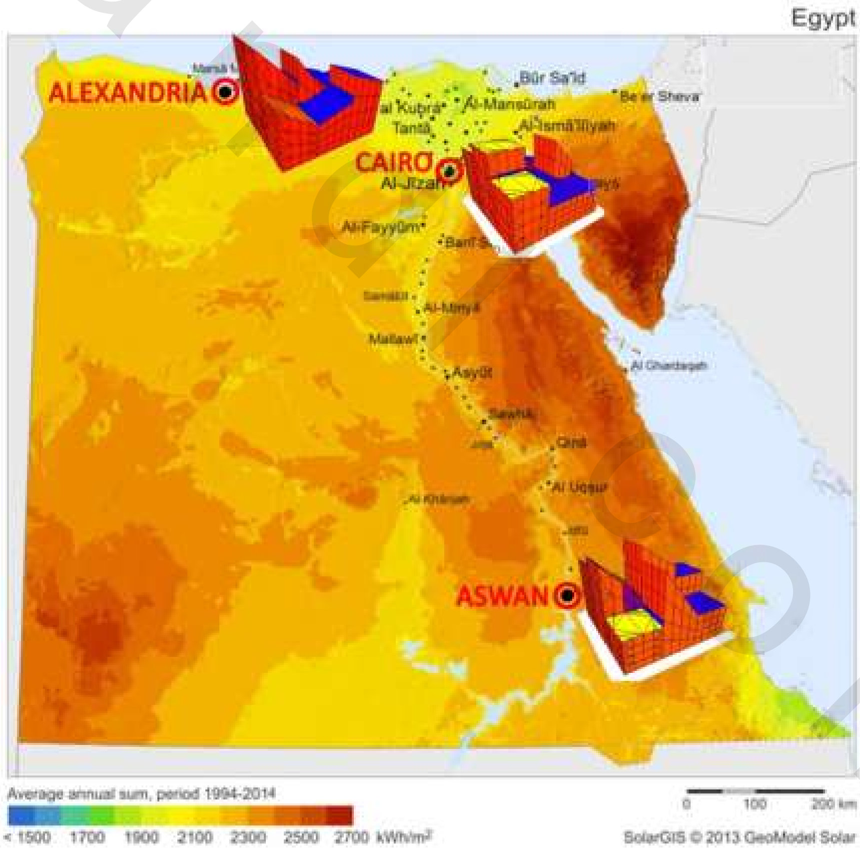


Figure (6- 12): Three sites for case study application of morphogenetic evolutionary computational design
Source: Researcher 2014

6.1.3.3. Evaluation

Typically, thermal analysis is concerned however; many factors contribute to the thermal comfort and energy draw of a building. Early trials in this investigation sought to find a hosing layout with minimizing the house's heating, ventilation, and air-conditioning load. The typical result was a building with no windows or only one window, as these structures tend to be better insulated. Designs that provide interior daylight are encouraged using a form of multi objective optimization.

Ecotect through GECO uses data from a weather file to model a climate. This data includes direct and diffuse solar radiation and temperature, as well as humidity and wind information. Ecotect is also able to calculate the daylight factor or percentage of outside daylight available indoors, as an intrinsic property of a point in space. Also Galapagos optimization used to adjust the deformation of outer material with relation to the used interior daylight. This will be studied in Egypt, where three difference towns or places will be studied as a site location for the proposed layout form optimization. Galapagos + Geco will work on finding the best form having the minimum solar and thermal temperature exposed on the surfaces and interior of the form. This will differ according to the site location of the form or model. These three sites will be Aswan, Cairo and Alexandria. See Figure (6-12)

6.1.4. MATERIAL FORM AND BEHAVIOUR

6.1.4.1. Emergence of geometric pattern:

The history of architecture has a broad range of tiling examples which are interesting to study and use for contemporary design applications. Material and Tiling are among the possible design issues with Generative Algorithms in Grasshopper and Galapagos.

There is a potential to design a motif and then proliferate it as a pattern in design space. It is possible to use a motif and repeat it like fabric.

Having a predefined pattern, one can use transformations to repeat it in the design space. Basically the pattern is generated out of some lines which connect certain points in space. So by generating these points in a desired order, it is possible to connect them together by lines and generate base lines of tiling material.

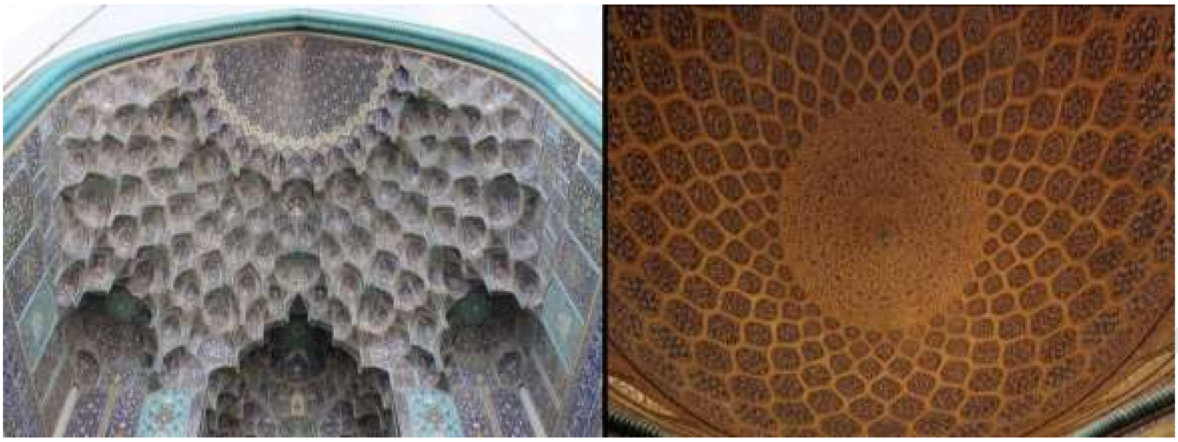


Figure (6- 7): Lotfollah mosque in – Royal mosque's muqamas (Isfahan) complex generative geometric work on dome and walls
Source: Wikipedia

Using those underlying rules as generative force of design in rhinoceros Galapagos, the written geometric pattern will be connected to the environmental status, which will change the pattern size according to the Geco thermal and environmental data to open and close, this will give more shades by thickening the wall dimension through rolling out or being medium opened to get more ventilation and finally closed to prevent direct unwanted sun light.

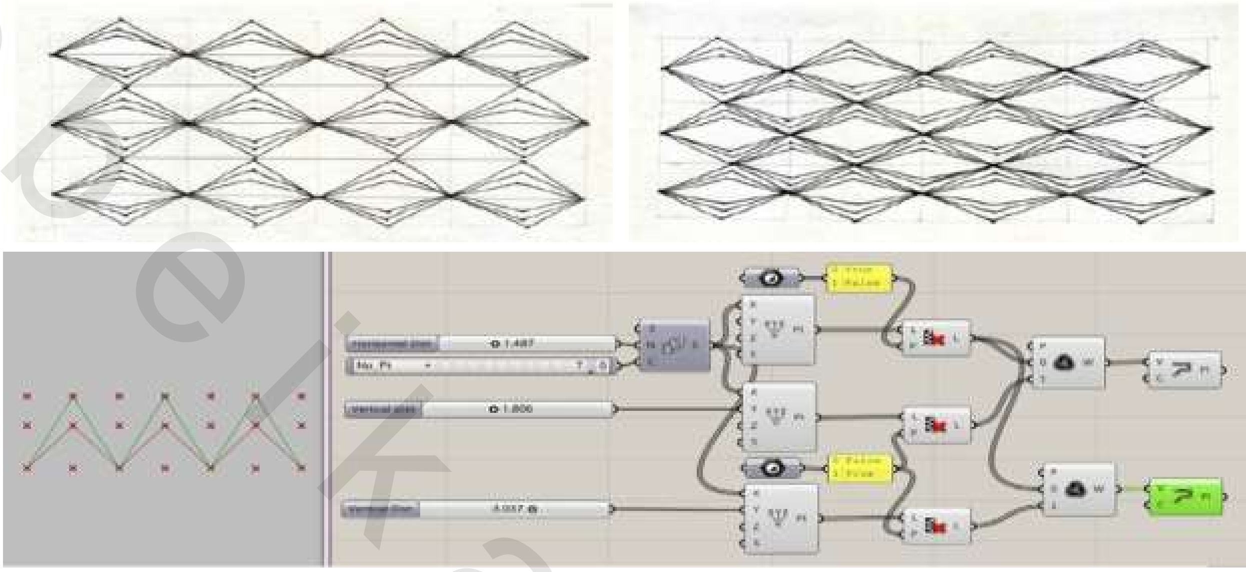


Figure (6- 8): The grasshopper modeling bullet
Source: (Researcher 2014); (Khabazi, 2012)

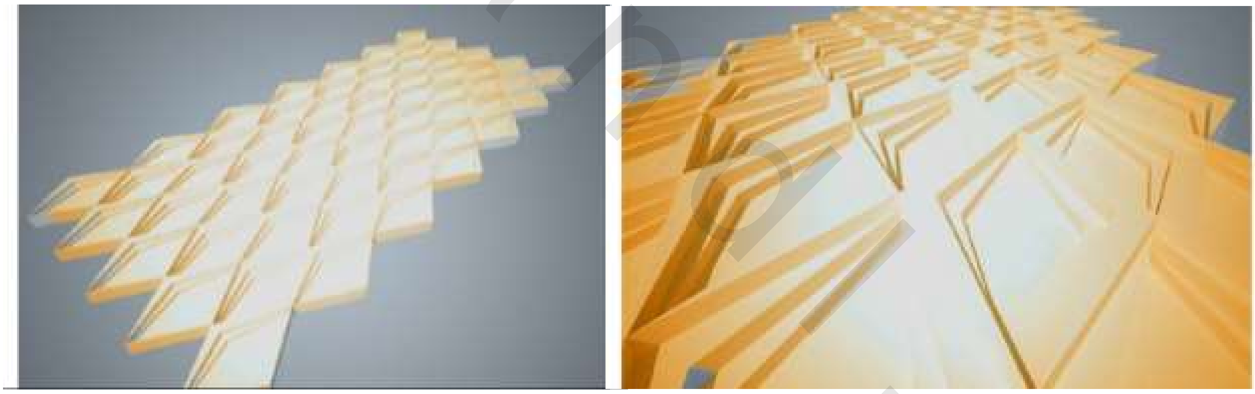


Figure (6- 9): The grasshopper modeling which will be added to the form – it will change in size, open and close.
Source: (Researcher 2014)

6.1.4.2. Ingrained Responsiveness – Genetics and bio-digital material:

(A) Adaptation: Nature has evolved a great variety of dynamic systems interacting with climatic influences. For architecture, one particularly interesting way is the moisture-driven movement that can be observed in some plants. Different to other plant movements produced by active cell pressure changes, as in the well-known example of the Venus flytrap. See figure (6-16)

(B) Self – organization: This movement consists of a passive response to humidity changes. It does not require any sensory system or motor function. It is independent from the metabolism and does not consume any energy. The responsive capacity is ingrained in the material's hygroscopic behavior and anisotropic characteristics. See figure (6-16)

(C) Behavior material and Environment:

Anisotropy denotes the directional dependence of a material's characteristics as, for example, the different physical properties of wood in relation to grain directionality. Hygroscopicity refers to a substance's ability to take in moisture from the atmosphere when dry and yield moisture to the atmosphere when wet, thereby maintaining a moisture content in equilibrium with the surrounding relative humidity. In this process of adsorption and desorption the material changes physically, as water molecules become bonded to the material molecules. See figure (6-16)

Figure (6- 10): Example of the Venus flytrap dynamic systems interacting with climatic influences
Source: (Menges, Reichert, 2013)

The previous tilling in figure (6-15) will be made with timbered wooden material with certain nature genetic properties. Hygroscopic behavior or genetic behavior is the basis here for simple, moisture-responsive parts that are in one embedded sensor, with no energy motor or regulating element. This enabled the development of a system that responds to changes of relative humidity by opening or closing the surface.

As all the responsive capacity is embedded in the material itself, no additional technical equipment or external energy is needed for the system to react to environmental changes within the geometrical pattern. See figure (6-17)

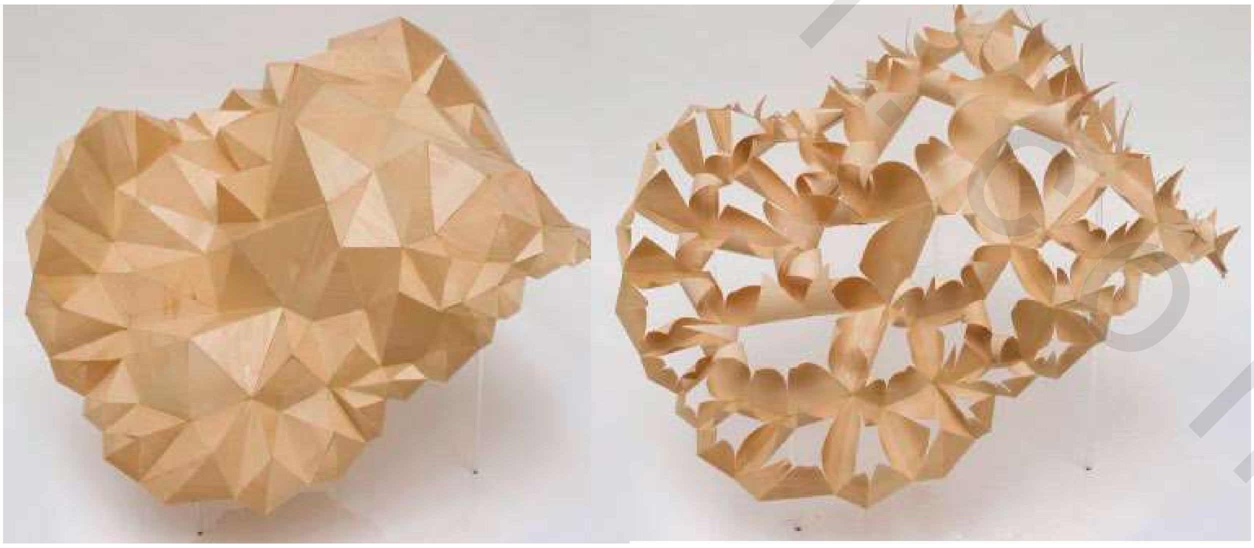


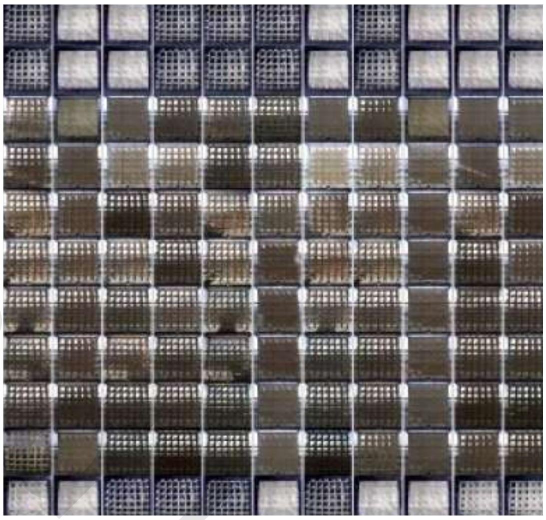
Figure (6- 11): Example for the chosen material in both cases - one when closed the other when rolled and opened.
Source: (Menges, Reichert, 2013)

This material simply is a timber genetic natural wood. This material has different sizes according to the thermal and environmental simulation study which change in size, open and close and changes its orientation to give the best shades and ventilation needed to the form. See figure (6-17).Where this material will be used after being applied to Galapagos simulation in Rhinoceros to adjust the material on the optimized chosen model; this model will use an Islamic motive to apply the Egyptian sole in the form's skin. See figure (6-17)
Natural systems embed all the responsive capacity in the structure of the material itself. Bio-digital responsive material systems that require neither the supply of external energy nor any kind of mechanical or electronic control, this material physically explains the possibilities this opens up for a strikingly simple yet truly ecologically embedded architecture in constant feedback and interaction with its surrounding environment.

6.1.4.3. Genetic Guides in Galapagos Grasshopper

(A)Genotype

Adding the environmental details from Geco and connecting the opening and closing of the timber material to the chosen optimized form from the previous section. The Galapagos role is to optimize and choose the best comfortable model with the best interior and exterior lighting, environment, ventilated and thermal model. This happen when the chosen material role outwards increasing the shaded parts on the form acting as outer louvers and getting much more inner ventilated zones, adjusting the material motive size according to the thermal details from the simulation by being smaller or larger in size or maybe getting solid part. See figure (6-18)



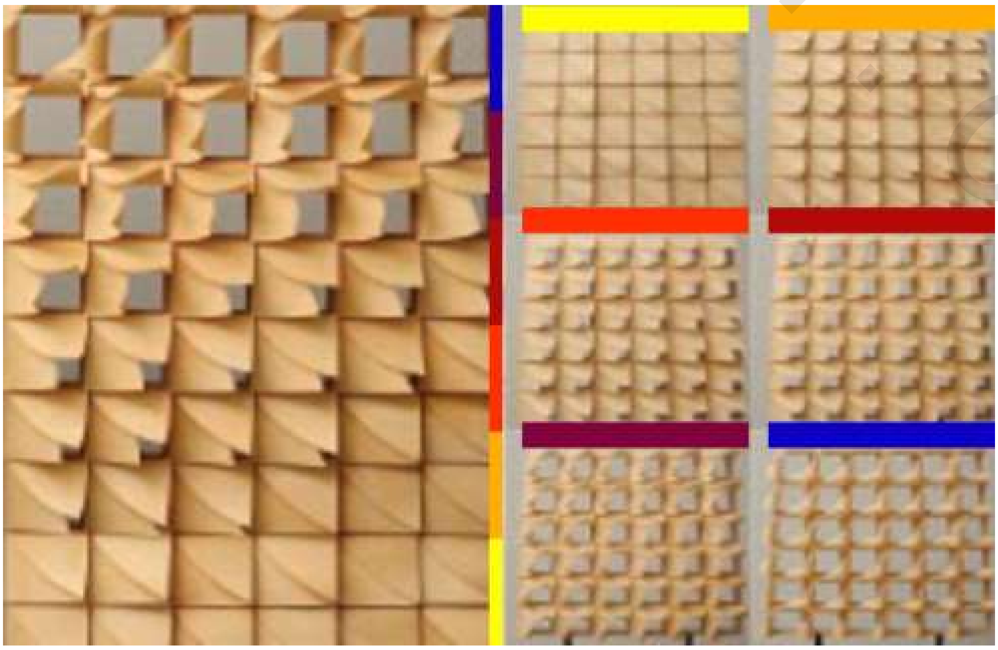


Figure (6- 18): Changing in material rolling is different according to the environmental aspects and zones orientation Source: (Menges, Reichert, 2013)

(B) Phenotype

The zone outer walls will have a wall timber responsive material openned, closed, reduced in size, applied on the entire surface or cancelled. This all is applied according to the environmental aspects according to the location of each model which will differ from Aswan to Alexandria, as in Aswan we have hotter weather and much more solar rays which effect the optimized model where we will find more solid thicker material parts in the south with little north ventilation effecting the timber opening due to the difference in humidity between both locations. See figure (6-18)

6.2.5. Final Generated GENERATIONS GENO Forms in the chosen locations

6.2.5.1. Cairo

Cairo's best generations were that of genomes: 3, 34, 41 and 46.One of these solutions in Cairo climate includes a south-facing face that provides a view in to the center zones, all of which are connected by openings which gives better ventilation, also mostly one or two high zones which provide shade and shadow on the other zones. The walls of the Cairo house are well suited to a hot climate but not as that of Aswan. Since the exterior walls on the east and more in the west side have a low thermal lag value, the roof is also made of this highly isolative material. The material of the east wall is slightly thinner; it still provides reasonable insulation. These walls receive the most direct solar exposure so our genetic material will prevent the heat from passing to the inside. The interior of the Cairo house are tall enough to contain a second story. Other remaining zones are short.

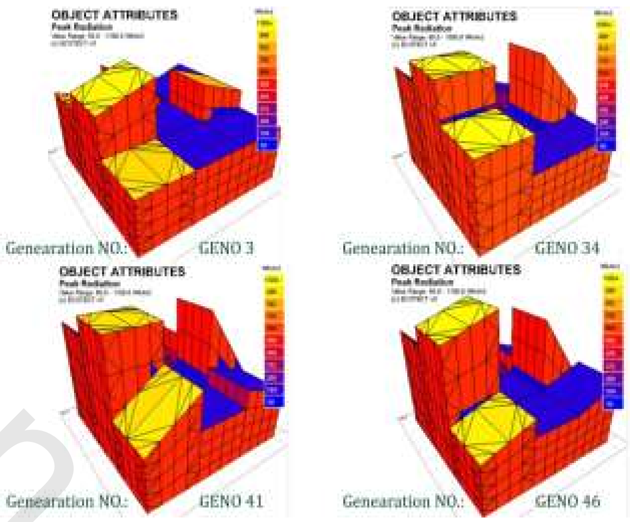


Figure (6- 12): Cairo's best generations – Grasshopper – Geco – Galapagos
Source: (Researcher 2014)

6.2.5.2.Aswan

Aswan's best generations were that of genomes: 4,8,11 and 33. One of these trials in Aswan produced several individuals with very tall zones on their south and west sides. While these towers perform poorly on their own, they have the effect of shading the rest of the house through most of the morning, which greatly reduces the amount of heat entering the other zones.

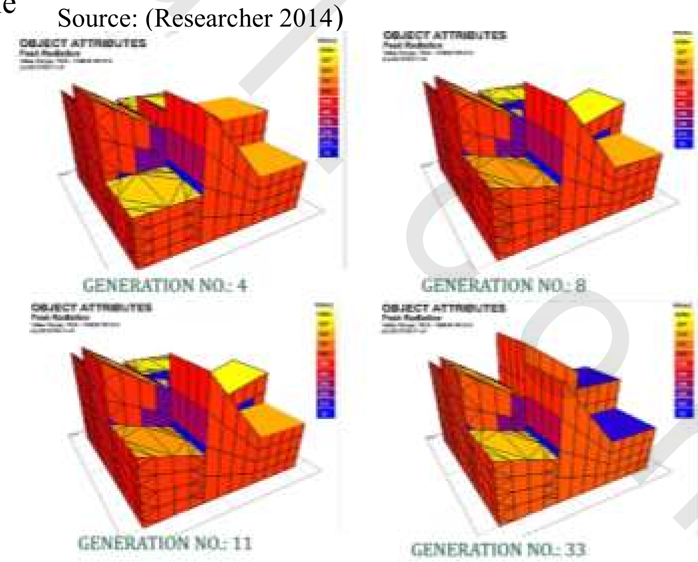


Figure (6- 13):Aswan's best generations – Grasshopper –Geco – Galapagos
Source: Researcher 2014

Often, some zones in these houses have the least possible height, causing the towers to become even taller to keep the total building volume constant.
The most successful individual from one of the trial in Aswan's climate has a roof slope that perfectly matches the sun's angle at days on august 30th. This angle minimizes the amount of sunlight hitting the relatively southern walls and roofs in a way that minimizes the surface area exposed to the south, east, and west. Also thicker walls can be present in Aswan's generation to reduce the heat of the sun, keeping a comfort interior temperature.
Since the center zone of the house's nine-square grid is always short, it can serve as a courtyard around which the other zones spiral. Also water from a fountain in the courtyard absorbs heat that would otherwise enter the zones around it. Brise-soleils over the large western windows given to the tower by the GA regulate the entry of sunlight.
This limits the amount of heat entering the tower during the day without adding the need for electric lighting in the evening.

6.2.5.3. Alexandria

Alexandria's best generations were that of genomes: 39, 44, 46 and 47. One of these trials in Alexandria produced several individuals with medium heights of zones. It applies the same concept of a zone higher than another to provide more shades on it. Also thicker walls can be present in the south and west zones.
Openings in the north and east walls can be applied in Alexandria's proposals with our genetic material to give the best ventilation, also some horizontal openings can be applied in the west walls to help the unit to be well ventilated as the wind direction in Alexandria is North West.

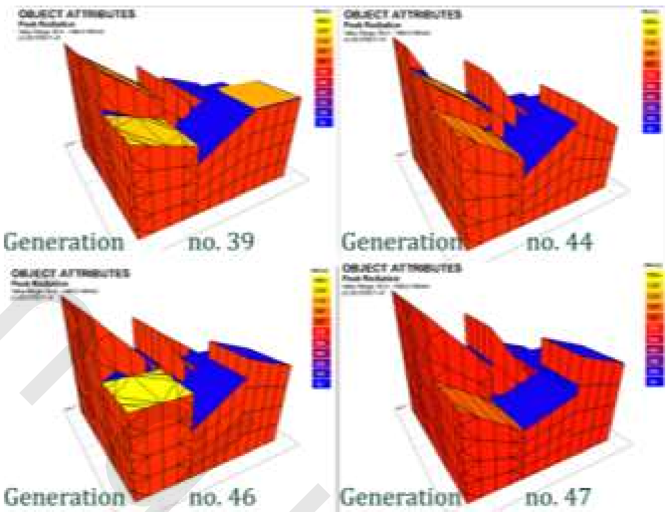


figure (6- 14): Alexandria's best generations – Grasshopper –Geco – Galapagos
Source: Researcher 2014

Another case can be found in Alexandria, which is applying solar panels on the unit roof, therefore a high thermal unit can be chosen with the best roof inclination absorbing sun rays and keeping the inner zones in the best comfort temperature. Alexandria is starting to apply this strategy to reduce electricity usage. Simply this result and many others can be computed to get these evolutionary results from our morphogenetic and evolutionary computational tool within a genetic and bio-digital content concept.

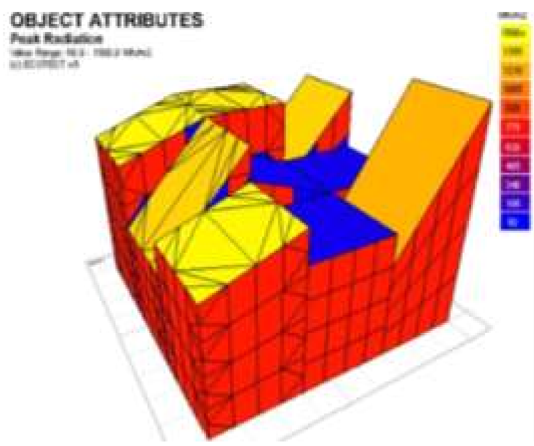


Figure (6- 15): Alexandria's generations with a bigger zones facing solar rays for using in a solar panel plans – Grasshopper –Geco – Galapagos Source: Researcher 2014

6.3. SUMMARY

This chapter discussed the digital evolutionary tools applying evolutionary designs through the use of the evolutionary algorithms with Galapagos optimization. Rhinoceros with its plugins acted as an evolutionary morphogenetic computational tool applying biological concepts, genetic process and genetic material.

This case study presents: 1- A simple plan layout, 2- 3d model form and 3- A proposal for the outer material using Galapagos in rhinoceros as an evolutionary morphogenetic computational design tool. It interacts with environment, applies genetic material and uses bio-digital logic in forming the design.

A model was presented using the evolutionary genetic tool in this study as a housing unit responding to environment and interacting with its surrounding to be built in new governmental towns and residential projects using a new evolutionary tool, any other inputs, changes or bigger projects can be made using this evolutionary tools and getting the best optimized solutions which made architecture design much easier to any architect.

Why using Rhinoceros?

A lot of soft wares apply evolutionary and genetic designs, but they mostly need a good even perfect knowledge of algorithms or scripting, Rhinoceros has the benefit that: the user does not have to know anything about scripting or algorithms or how the surfaces are created. It is merely required that the user has a conceptual understanding of the nature of EAs and the growth process. The outputs of the system are ordinary 3d objects and the user can export the final product to any other or continue editing in the rhino which is good modeling software with good rendering quality as it was used in both the residential plan layout and in the form genetic optimization and material forming. Also it has the genetic Galapagos plugin and the environmental ecotect (Geco) plugin which combines many optimization points needed in any design.