https://erjm.journals.ekb.eg
ISSN: 1110-1180

DOI: ---------

ERJ
Engineering Research Journal
Faculty of Engineering
Menoufia University

Boosting the Design Process Using a Proposed Methodology Based on Computational Design

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ABSTRACT
Architectural generative design is an iterative technique that uses an algorithm to produce a small number of outputs in order to meet specific requirements. It is considered a recent methodology that has been successfully applied to solve various optimization problems in several domains of architecture and planning. It allows users to explore, optimize, and evaluate data-driven design alternatives based on project goals, constraints, and inputs. For the first time, engineers and designers can utilize new technologies offered by artificial intelligence to explore multiple design alternatives and weigh the trade-offs in order to identify improved design outcomes and make data-informed decisions faster than ever before. The normal design process depends on the designer's mind. It's a never-ending cycle of redesign and review of each stage. Optimization has a complex effect on a design by finding a solution in various ways that innovate ideas, provide alternatives that can be adapted from parameters, and encourage the designer to see an open vision. This paper aims to illustrate and design multiple alternatives that can assist designers in the field with innovative solutions and easier, faster work. It can mimic grasshoppers' natural feeding and swarming behaviors and is an intriguing swarm thanks to new technologies provided by an intelligence system.

Keywords: *Optimization, design thinking, computational design, Algorithm, Generative Design.*

1. Introduction

In the last three decades, the area of optimization using meta-heuristics has gained increasing interest from academics and researchers, and several meta-heuristics are being regularly proposed for solving complex real-world problems in different fields such as engineering, computers, medicine, economics, etc. The development of new creative techniques in the 1950s and design methods in the 1960s gave rise to the concept of design thinking as a specific method of problem-solving through creativity. These developments drew inspiration from psychological studies of creativity from the 1940s, such as Max Wertheimer's "Productive Thinking" (1945). In "Creative Engineering" (1959), Arnold distinguishes four areas of design thinking (Rowe, G. Peter, 1987). (1) Novel functionality, i.e., solutions that satisfy a new need or an existing need in a brand-new method; (2) improving a solution's performance levels; (3) reducing production costs, or (4) making it more marketable. Although Bruce Archer's "Systematic Method for Designers" (1965) (Visser, W. 2006) was primarily focused on a systematic design process, it also underlined a desire to expand the scope of traditional design: it was necessary to find a way to bring design thinking into the fields of ergonomics, cybernetics, marketing, and management science. A 1982 article by Nigel Cross, "Designedly Ways of Knowing," identified some of the inherent features and skills of design thinking that make it useful in general education and for wider audiences. (Abrell T., 2014) Peter Rowe's 1987 book, "Design Thinking," describes methods and approaches used by architects and urban planners; the term was extensively used in the early literature on design research (Cross, Nigel, 1982).

The research contributes to adapting technology to help an architect innovate a new process methodology. Helping to dig deeper into the field of generative design. It was chosen because it is a new addition that has not yet been clearly addressed in the research. The program was used to develop the field and help the students innovate in planning, deducing many solutions, and facilitating brainstorming. And talking about the history of using the program, its appearance, and its development.

When considered in the context of higher education in general and architectural education in particular, such reflections assume greater significance in the scope of architectural education. The vain hope that our piecemeal integration of new technologies will somehow enable us to cope with the future market is frequently the result of failing to recognize the radical shift our discipline is undergoing and miscalculating the rate of this change. (Vahid Vahdat, 2020).

The research contributes to adapting technology to help architects innovate new design process methodologies. Helping to dig deeper into the field of generative design. It was chosen because it is a new addition that has not yet been clearly addressed in research. The grasshopper was used to develop the field and help architects innovate many solutions to facilitate brainstorming and concept phases.

This paper will discuss how meta-heuristics can influence the design perception in learning, while technology can be tailored to various parameters and situations. Today, the current design methodology depends on the student's thinking and knowledge gained from different situations while trying hard to organize it into a better idea, but it needs exercises to get better in a short time, so adjusting the technology can help in a lot of ways to get better at visualizing our ideas in the short term and develop ideas.

Minds think differently from one another while brainstorming ideas and creating new ones using an algorithmic methodology called meta-heuristics, but we fall into a complex map with no references to what we will be thinking. Optimization is about reducing the complexity of a complex map to create an understandable path of alternatives.

Firstly, the research discusses the design process and defines the design thinking process for the designer. Next is the process of understanding computer science and artificial intelligence technology. Then, defining the optimization process and how to develop it then we discuss two types of optimization examples. Finally, what can be developed from optimization that helps the designer, and what are the applications for it?

2. Current methodology 'design thinking'

Design thinking is a term used to represent a set of cognitive, strategic, and practical processes by which design concepts and aspects of design thinking have been identified through many studies. (Visser, W. 2006). Design thinking is fundamentally an ideation process with a human-centered emphasis. It energizes organizations and businesses to center on the human point of view over all else and to construct this center into each step of the product development cycle (Chun-Ming Yang, 2018). This implies designing items and services with people's needs and preferences solidly in mind (Michael Shanks, 2014).

Design thinking is considered a planning methodology that gives a solution-based approach that helps solve design and planning issues. By comprehending human needs, re-framing the problem in human-centric ways, and generating numerous ideas in conceptualizing. (2021, Ruma, Finland). Fig 1.

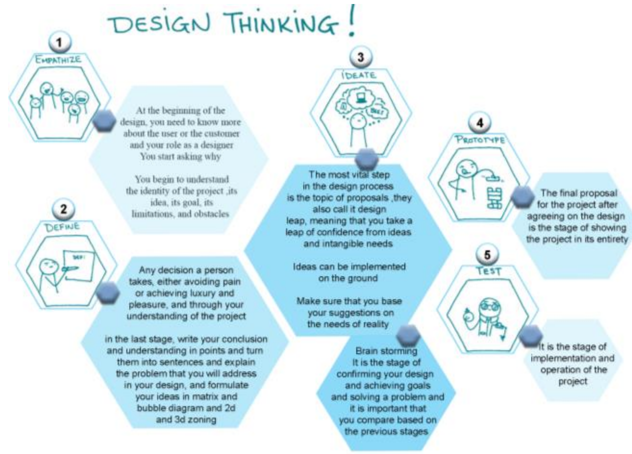

Figure 1- Design thinking methodology Source: (Abrell T, 2014)

3. Computer science and AI (Artificial Intelligence)

Computer science is development of technology from how it affected designer in the past as it was simple point or work in designer mind to system and software develop and ideate. machine learning and AI are working in a parallel path to solving Concurrent problems, effort is involved in realistic representation and modeling. Soft wares for complex systems also present challenges in reasoning under uncertainty. Adaptive software presents challenges in machine learning and reasoning under uncertainty. Interface technology develops collaborative (with the user) problem-solving and virtual reality, Speech synthesis and recognition present challenges in collaborative problem-solving machine learning/adaptive systems, and virtual worlds. Neural networks present challenges in machine learning, reasoning under uncertainty.

The ability to design and evaluate in software a sophisticated new weapon system, including carrying platform, sensors, weapons, communications, control systems, and human decision makers. This "prototype before build" capability (smaller-scale examples of which include Boeing's use of computer-aided design (CAD), and computer-aided software engineering.

Understanding how people solve problems is requisite to determine whether or not technologies can aid in the process. A number of studies comparing problem-solving with and without supporting technologies have been made over the past several years. Many of them have found that formal meetings using group decision support technologies improved the productivity of groups, shortened the time to final decisions, and in some cases quantitatively improved the decisions themselves.

The grand challenge in machine learning and adaptive systems is to identify a scientific methodology and theory that characterize classes of practical learning and adaptation problems. These characterizations would then be used to evaluate performance as select solution methods, and eliminate heuristics as much as possible.

Progress in this area would result in better validation techniques and a guarantee of performance in the numerous autonomous applications for which learning and adaptation are currently proposed.

Complexity can be due to multiple stakeholders, organizational structures, or steps that must be followed in a process. And they are open systems with stabile patterns but critical transitions as well as coupling rules, emergent Relationships are non-linear (Battram, 2002).

A complex organization has a larger size of its organizational structure or has a higher number of resources in any division, project, or team it is chaotic systems remain deterministic

Long-term behavior can be predicted by initials and condition.

Methods are available for the computer-aided solutions of even highly complex problems; if

(1) They are governed by stable constraints or rules;

(2) They are solvable using well-understood processes and resources, under control of the responsible manager;

(3) They are analogous to similar situations within the knowledge or experience of the Manager and organization. (Okes, Duke.2003).

A complex system can be defined in steps or processes that help the system work in an open system while complexity for organizing the open system to discover the hidden patterns to solve the complex building requirement to be excite.

4. Levels of design comparability

Since the advent of computers, designers have employed them for computations, and before long, the terms (computer-aided design) would appear. CAD/CAM (computer-aided manufacturing) has appeared. (Gabriela Celani, 2012).

The movement of industrial tools and machinery are controlled by pre-programmed computer software in CAM, which is based on Computerized Numerical Control (CNC).

From many different industries, including Architecture, Automotive, and Aviation, CAD software is utilized to support both engineers and designers.

Despite the fact that the two names refer to different concepts, CAM has been using CAD more and more, leading to the frequent use of the term "CAD/CAM". Fig. 2 (Grasshopper, 2021).

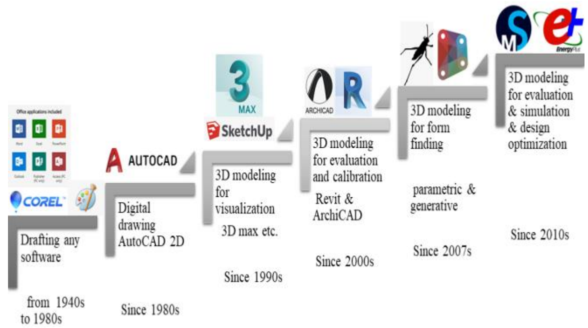

Figure 2- CAD/CAM Software evolution
Source: Grasshopper, by author

5. Computational design

A thinking methodology that assists in reaching the target in all of the ways that have categories or ways of defining the process while all giving the same product with different processes. Computers have been referred to by a variety of words, such as digital, computational, and algorithmic. When professionals began to apply computers in design, different uses were naturally named "digital design," "computational design," algorithmic design," and so on. However, overlap and ambiguity ensued, which we now intend to reduce. (Kvan.T., 2004). Thus, we begin by distinguishing computational design from digital design. We consider digital design to be the use of computer tools in the design process, whereas computational design entails the use of computation to develop designs. The computational design approaches are generative design and algorithmic design and parametric design and they can give you same output with different input resources and the research about generative design approach.

5.1 Generative design (GD)

Generative design must be differentiated from other terms, such as parametric design. Then we define "generative design" as a design paradigm that employs algorithmic descriptions that are more autonomous than parametric design. In which 3D models are created and optimized by computer software. In generative design approaches, after starting the generative process, the system executes encoded instructions until the stop criterion is satisfied. Consequently, generative design-based methods can generate complex outputs even from simple algorithmic descriptions. (L. Bruce Archer (1965).

5.2 Algorithmic design (AD)

The algorithm is frequently difficult to relate to the output produced, making it challenging to predict the result from reading the algorithmic description alone. A set of mathematical guidelines or instructions that aid in computing a solution to a problem is known as an algorithm. Nonetheless, it provides a finer degree of control, facilitating debugging and maintenance tasks.

5.3 Parametric design (PD)

PD is a method that uses parameters to symbolically describe designs. As an illustration, symbolic parameters with defined domains are used to create walls instead of exact placements, lengths, heights, and thicknesses. As a result, a set of walls is figuratively represented.

6. Optimizations

The optimum of a system is its most desired configuration, whereas the term "optimization" comprises the methods and techniques used to look for it, according to the Latin word "optimum" and its initial uses in biology in the nineteenth century. The mathematical components of architectural design provide a comprehensive and precise definition of optimization: with extreme synthesis, optimization may be traced to the pursuit of maximum (or minimum) points of certain functions related to performance. This approach may concentrate on the quantifiable characteristics of the architecture and what we choose to optimize when applied to architectural design, as it will be described in this paper. an act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible.
Grasshopper is a visual programming language and environment that runs within the Rhinoceros 3D computer-aided design (CAD) application. The programmer was created by David Rutten at Robert McNeel & Associates. Programs are created by dragging components onto a canvas. The outputs of these components are then connected to the inputs of subsequent components. Grasshopper is primarily used to build generative algorithms, such as for generative art. Many of Grasshopper's components create 3D geometry. Programs may also contain other types of algorithms, including numeric, textual, audio-visual, and haptic applications. The inputs of succeeding components are subsequently coupled with these components' outputs. Fig3,4.

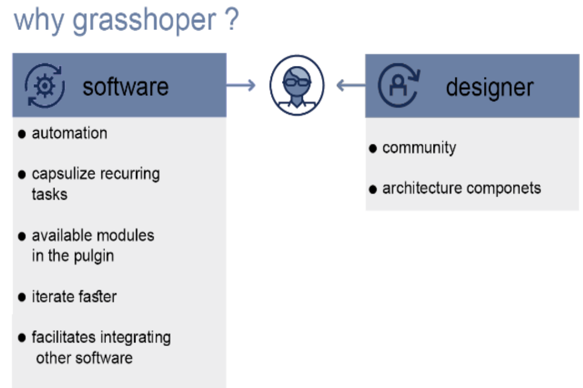

Figure 3- why grasshopper, Edited by autho

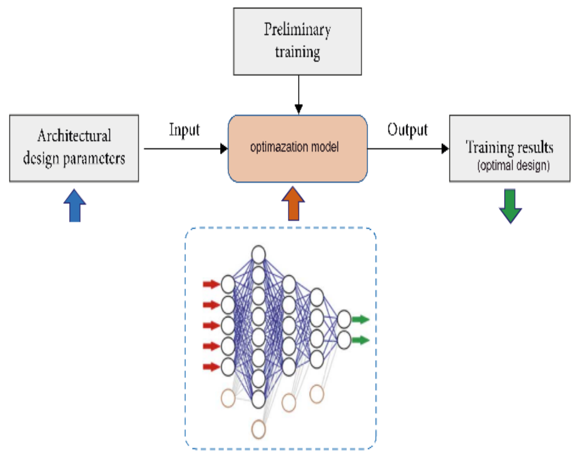

Figure 4- Optimization model process (the authors)

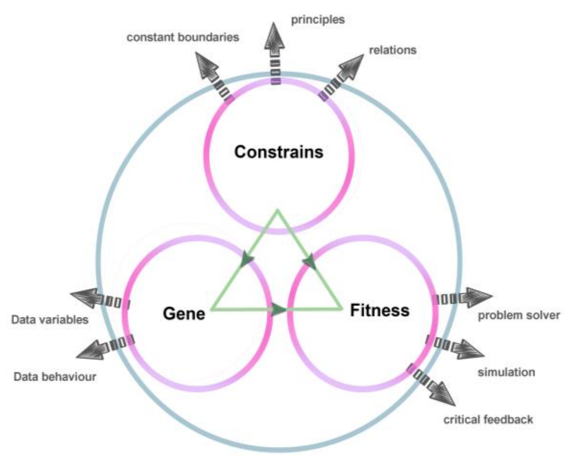

Figure 5- Galapagos inputs

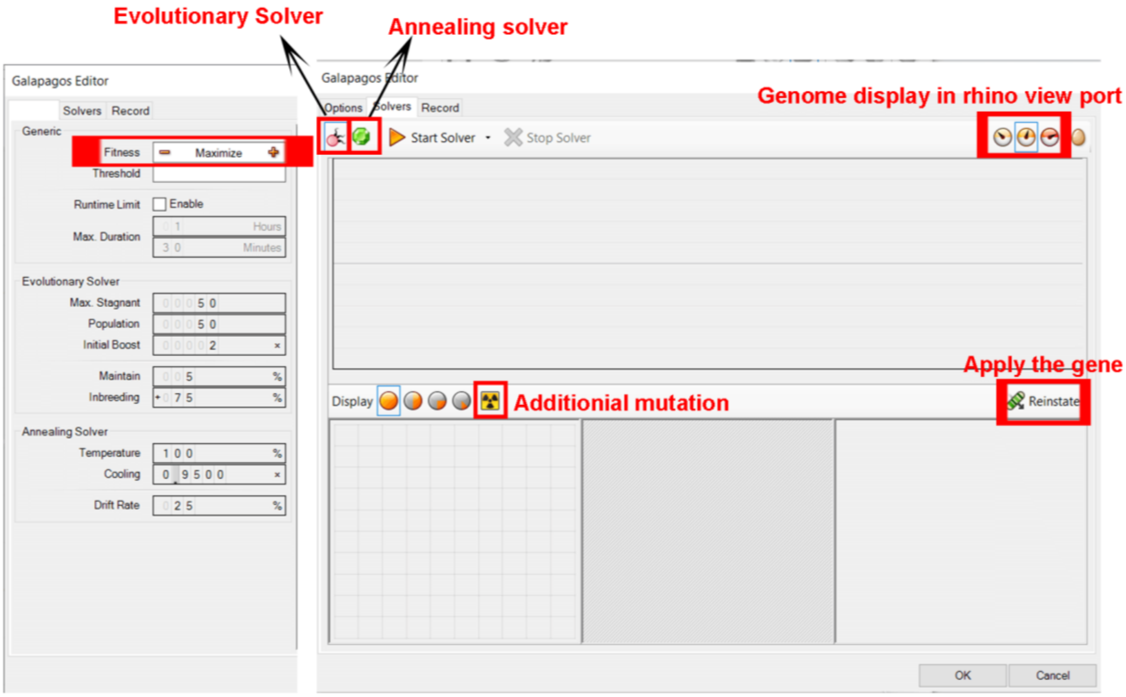

Figure 6- Interface of galagopes

6.1 Single-based Algorithms

The principle of single-based meta-heuristic algorithms, also called trajectory calculations, is the generation of a single arrangement at each run. This arrangement is enhanced using the neighborhood component. Several of the popular single-based meta-heuristics fall into this area. As example 1, it depends on the single data entry to multiply, process, and produce results. There are numerous solutions that rely on a single piece of data.

6.2 Population-based Algorithms

Population-based meta-heuristic calculations produce a set of multiple solutions (population) at each run. The class of population-based meta-heuristics can be classified into four main categories: evolutionary-based, swarm intelligence-based, event-based, and physics-based into four main categories: evolutionary-based, swarm intelligence-based, event-based, and physics-based.

That depends on many inputs and outside effectors, and then it multiples the input with outside effector conditions and results in a variety of solution

7. Existing optimization tools in grasshopper

It's a program in the grasshopper that solves the problem in minimum and maximum range of collision between data variables. It has two types of solvers traditionally; the optimization problem is done by coding. However, few designers have any experience with coding in the realm of design. Thus, "both evolutionary and gradient-based solvers exist in parametric software, including Galapagos for Grasshopper" (Zhouzhou Su, 2015).

It has capabilities like forcing diversity of answers, looking for trade-offs, altering search objectives midstream, and visualizing and exporting results, as seen in (David Rutten, 2010). A single objective optimization GA tool in Grasshopper A user only needs to define the genome and modify the settings such as population size and mutation rate in the Galapagos (Jingyi Liu, 2020).

When using galagopes designer decides the constrain of the problem needed to solve, gene is data parameters with range of variables and the fitness is alternative point needed to be solved**.** Fig. 5, 6.

8. A case study in optimization design alternatives

The research about the optimization alternatives problem solving the idea of optimization is various, it depends on the designer design thinking and challenges in the design approaches as example:

Case study: 2D planning Spaces

This project can be called a population-based algorithm as it gives a variety of random seeds in one solution as well as the planning pattern in each solution. This project experiments with the idea of the module grid in 2D while generating spaces.

The evaluating points (spaces area and the total width) are the data variables' genes and the space area calculation is the fitness, while the area of undefined shapes is divided into rectangles that's is link to each other.

Design objectives is Solving 2d planning spaces and controlling area zones while computing design variables such as orientation, planning, site analysis, and design decisions.

When computing spaces, the module grid while solving the intersection between spaces the fitness guideline for controlling its area variables, because area changes depending on the mathematical equation of area equal width *length and solving the space into rectangles in addition to find the link in changing its form. The steps for the process are:

Step1

- Write total area& write the total width or length and use the equation area=w*l and find the conclusion length this define the form outline as when the total area or the total width changes the deduced length is changing
- Deicide min and max area of spaces and that is the variable gene. Fig. 7.

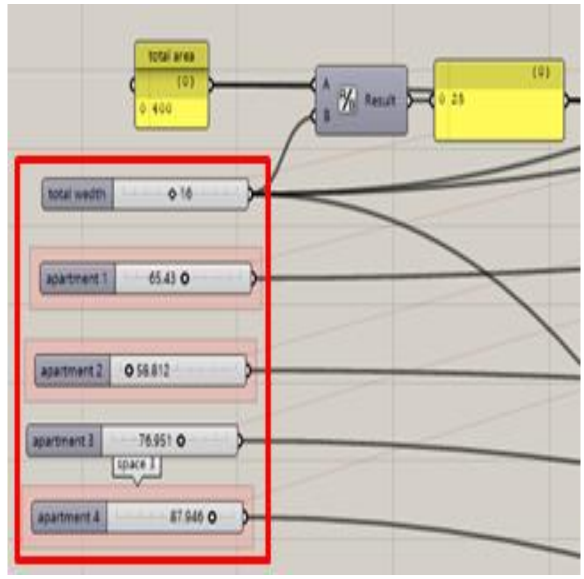

Figure 7-Optimization model process step1 (the authors)

Step 2

- Construct the module to frame the outline and inside lines as this module is constructed on the total area dimension as input and it helps in forming similar solutions in the Galagopes plugin and its output the construct lines.
- The output depends on the module as it's a reference for the outline spaces. Fig. 8.

Step 3

- find the intersection point and construct the need spaces as the intersection Point is the linked point to spaces as its fixed point to deconstruct the space into rectangles and calculate the area as deduced the motion in x direction from the module to the variables point parameter same in y direction.

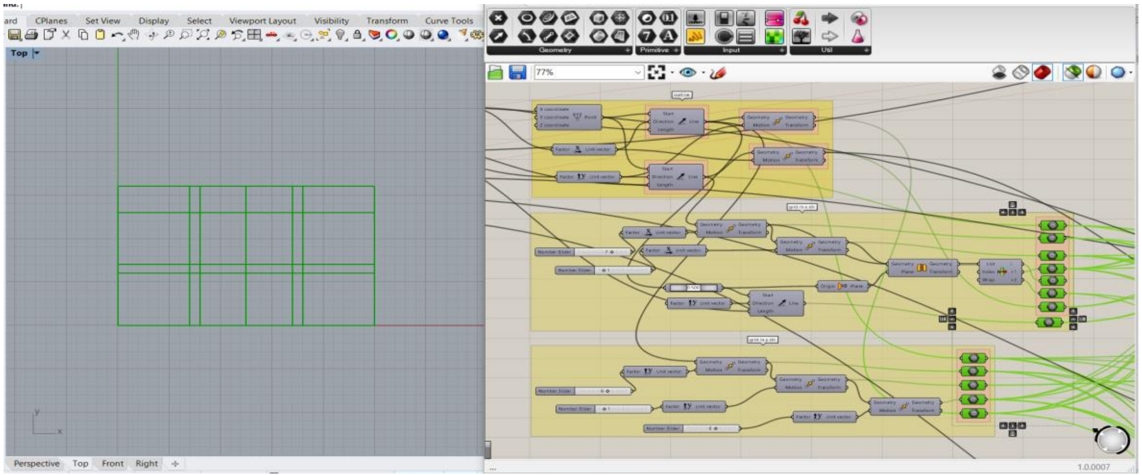

Figure 8- Optimization model process step2 (the authors)

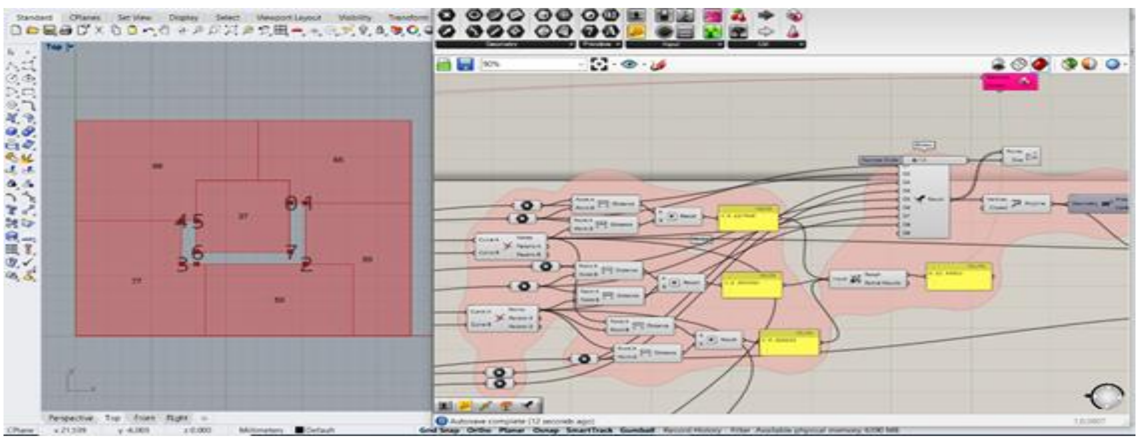

Figure 9, 10- Optimization model process step3 (the authors)

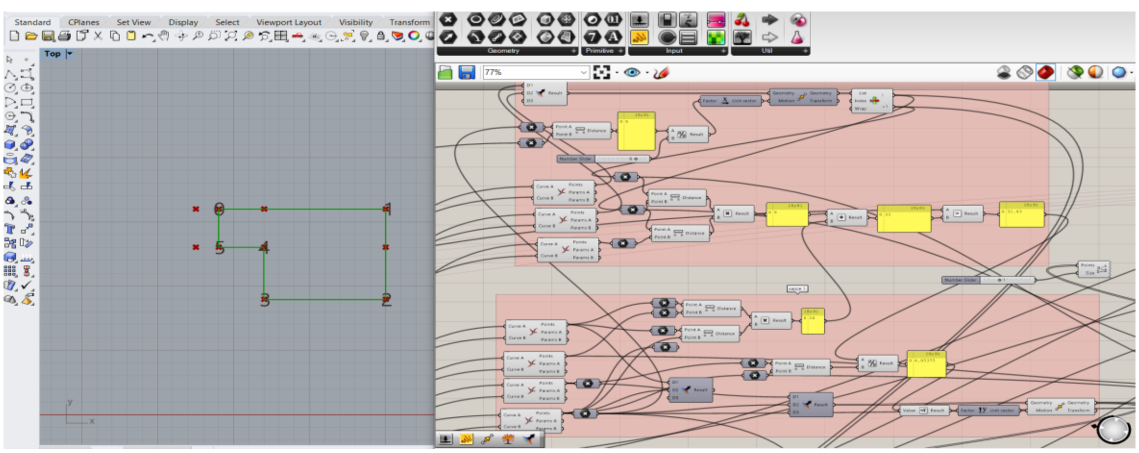

Figure 11, 12- Optimization model process step3 (the authors)

The area is parameterized as you find the distance between point and multiple the dimensions and subtract from the total area. Fig. 9, 10.

- The space construction depends on the geometrics analysis as you can form space from multiple shapes and mass addition for area and parameterize the variables of the form points.

- (0-1) *(0-7) as first rectangle area, (4-5) *(5-6) as 2nd rectangle area, (6-7) *(6-3.1) as 3rd rectangle area, the total area is need min or max range depending on the other Spaces controlling its point (fitness solution). Fig. 11, 12.

Notice every space is constructed on the parameter of the neighbor space

9. Optimal design

A strategy for parameter optimization to produce optimal designs. To establish a promising search region (or regions) for optimization, many distinct designs (design alternatives) and space formulation strategies—explicit, interactive, and autonomous—are proposed. Fig.13

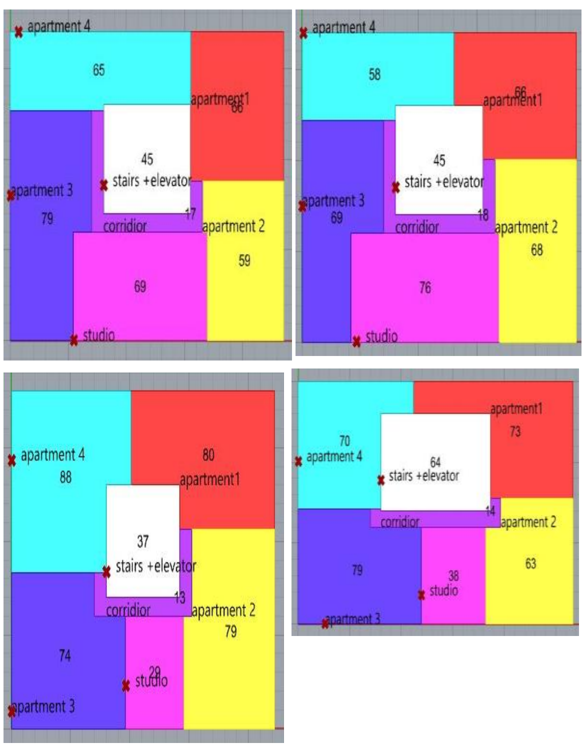

Figure 13- Optimization model final step have four proposals (the authors)

10. Results

The paper's objective is to present and develop various options that can aid designers by providing innovative solutions and improving their efficiency. The suggested computational design methodology enables users to explore, refine, and assess data-driven design alternatives based on project objectives, limitations, and inputs. The software used in the study facilitates creative planning, the identification of multiple solutions, and brainstorming, which enhances building performance. The optimization process described in the paper has versatile applications, including generating ideas for large-scale urban motion or determining the 3D layout of spaces in zoning and planning high-rise structures.

11. Conclusions

This work was an attempt to present, discuss, and analyze the state-of-the-art of the GOA algorithm. The research started by first discussing the methodology of the design thinking process. It was discussed that several relevant keywords were used, and the best publications were selected using a number of criteria to ensure high-quality research outputs. Then, the inspirations and mathematical models were presented. The main part of this work was the discussion and criticism of variants, hybrids, and applications of the GOA in the literature.

Model-based optimization is a cutting-edge optimization technique that is particularly well-suited for time-consuming performance simulations. Optimization, whether formal or periaortic, has long been regarded as a crucial component of design.

The relationships between optimization's effectiveness and its capacity to boost creativity show that it is useful as a design exploration tool rather than an engineering instrument. Efficiency is the most crucial aspect of ADO tools, followed by the ability to see optimization processes clearly and the availability of a variety of designs. Better visualizations and design space exploration are promised by interactive, multi-variate visualizations and dimensionality reduction. Detrimental buildings through sub-optimal planning and design.

In order to enhance building performance, this paper proposes a thorough strategy for designing regular architectural spaces more efficiently. The software was utilized to advance the industry and support creative planning, multiple solution determination, and brainstorming. The optimization can be used in a variety of applications that take a design from its initial iteration to an adult stage with herisortic computer science memory that can be modified reputedly, such as idea generation for urban scale of motion or 3D orientation of spaces in 3D zoning and planning towers.

In this paper, the users are the designers, who can work on training exercises as well as do practical design depending on the designer's mind and the tools used in this process from learning to practicing optimization.

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