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Genetic Algorithms Application in Urban Morphology Generation

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ABSTRACT

Urban morphology generation is the most accurate terminology that describes changing process required to be created by an adaptive generation system. The research introduces an Evolutionary design system as an example of an urban morphology generation system (Genetic Algorithm), which targets several generations. Accordingly, the research aims to introduce the applications of genetic algorithms in Urban Morphology. First, the research introduces a review of the theoretical base of computerized generation systems suitable for urban generation, focusing on genetic algorithms, the basic definitions, and the generation process. Then, the paper analyzes fourteen highly cited studies; the latest five studies will be compared to highlight the familiar and different aspects of the generation process. The comparison indicates the variety of implementing different applications of genetic algorithms in urban morphology generation. After analyzing cases, the research indicates that promoting walkability, enhancing microclimate, achieving functional needs and increase site accessibility are the most dominant objectives of applications of genetic algorithms in urban morphology generation. Furthermore, the research highlighted the simulation strategies, urban morphology variations, and the number of objective functions as the primary constraints, which influence the generation process.

Keywords: Genetic algorithm, Evolutionary design, Urban morphology generation, Parametric model, Optimization

1. INTRODUCTION

A city's design is a complex undertaking that necessitates the definition of various aspects and the consideration of several performance criteria. It is a struggle for urban planners, particularly in emerging nations with fast population expansion and urbanism, to continually expect new suburbs or entire cities in a short amount of time while guaranteeing optimum quality by using Computational approaches [1]. Because of the complexity and instability of the urban environment, static and solid judgments in urban design are questioned. Cities are complicated and self-organizing, much like any other open system. As a starting point for urban design, the project context is continually changing in a non-linear manner [2]. New ideas and different sorts of research are being discussed and promoted as a viable foundation for incorporating rule-based

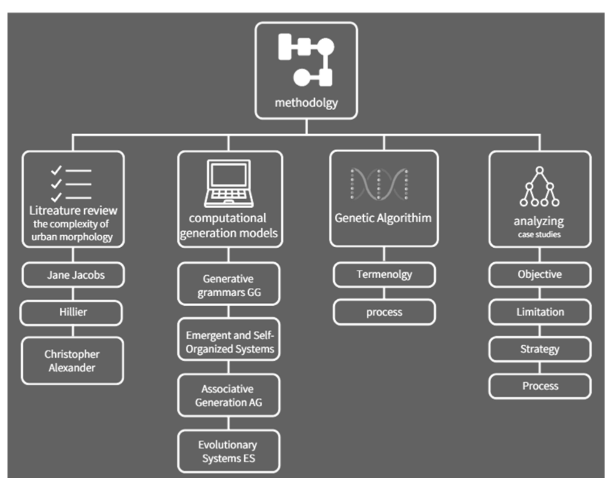


Figure 1: Research Structure (by researcher)

generative methodologies into urban planning and design. This integration is suitable for dealing with the city's complexity [3]. Moreover, it aids in constructing spatial differentiation patterns associated with perceptions of urban culture and the traits that make a city a desirable place to live.

Jane Jacobs explains that local components of urban form (i.e. Streets, buildings, and blocks) were addressed as the fundamental units of variation within the collective urban fabric, to be created through time [4]. As a result, a new school of urban studies has emerged, focusing on understanding and analysis rather than prediction. The new method might be referred to as generative planning [3], other notable planners have taken up the problem of dealing more successfully with "organized complexity." Bill Hillier created the concept of "space syntax," a methodology for mapping the connective links within a spatial system and expressing the global connective qualities of each element [5]. Hillier has created an excellent method for displaying the res in discrete units [2]. The concept of patterns is one of the most successful computational concepts, with applications in various fields, including urban design [6], which has been used in many knowledge areas namely in the field of urban design. His logic is introduced when a recurrent problem occurred in the urban contest. His main concept involves introducing a genetic solution to the same problem whenever such an occurrence is detected in a particular context. A set of patterns defines a pattern language. Previous work showed that urban design generic patterns could be encoded using generative rules in the form of discursive grammars to provide formal solutions to practice [7]. By using "rules of wholeness," Christopher Alexander hoped to construct "a new theory of urban planning that aims to recapture the process by which cities evolve organically." He proposes a means for recapturing this quality in a modern setting — not through a traditional master plan but a process involving the successive involvement of many participants [2].

The research discusses the complexity of urban morphology, explain the different visions of several researchers, Then, it introduces several computational generation models. Next, the research focuses on the Evolutionary design system (Genetic Algorithm) in urban morphology as one of the most suited urban generation systems dealing with this constantly changing process since it targets several design generations. In addition, the theoretical foundation of genetic algorithms and many computerized generation systems employed in city generation will be reviewed. Finally, the research selects the latest studies, which deals with applying the genetic algorithm in urban morphology generation. The selected studies have been analyzed and compared to extract several genetic algorithm applications in urban morphology generation. The research methodology is shown in Figure 1.

2. COMPUTERIZED GENERATION SYSTEMS

Since the 1960 s, generative design systems have been created. The primary goal of the urban generation is to improve the quality of the urban environment and inhabitants' interactions through optimizing different variables that affect people in space to develop a predictive model.

It is conceivable to include a computerized operation to generate urban fabric that adapts itself over time as it converses with constantly changing conditions, maintaining an equilibrium state when confronted with constant change. Many of them have common roots or characteristics that may classify various systems [8]. The primary motivations for using generative design (GD) systems in urban design are to leverage computational capabilities to assist human designers and/or automate elements of the design process [9]. The Cambridge Dictionary defines generative as the "capacity to produce or create something [10]. In generative design, there are many diverse approaches. As a multi-objective optimization as Generative grammars, Evolutionary Systems, Emergent and Self-Organized Systems and Associative Generation, each system has its definition and types, as shown in **Table 1.**

Table 1: The classification of Generation Design systems in urban studies, the researchers after [8;9;10;11;12;13;14]

GDS	Definition	Types
Generative grammars	It is developed using transformational principles that may be applied recursively. It developed into many shapes for various uses.	**Shape grammar:** The design is created through the interaction of elements. Design generation entails changing (adding, removing, or replacing) the "elements" and defining or altering the "relationships" between the "elements" via shape rules. **Graph grammar:** were initially developed in computer science and are especially suitable for computer implementations. **L-systems:** lSs are mathematical algorithms known for generating factual-like forms with self-similarity.

Evolutionary Systems	Evolutionary computation is all about search. Thus, when we employ a search algorithm in computer science or artificial intelligence, we characterize a computational issue in terms of a search space, which may be regarded as an extensive collection of potential solutions to the problem. This type of generation method is combined with other systems in generation process.	There are four major types of the generative algorithm: • The Genetic Algorithm (GA), • Evolutionary Programming (EP) • Evolution Strategies (ES) • The Genetic Programming (GP) Include several generation techniques as: • Generative design systems (GDS) • Evolutionary Multi-Objective Optimization (EMO)
Emergent and Self-Organized	Emergent systems are generative design systems that produce results from self-organized components. F-organizing agents shape the final form by interacting with one another and with their environment.	**Cellular automata (CA)** is a group of cells on a grid that alter over time in accordance with a set of guidelines established by the condition of nearby cells. **Swarm intelligence:** originated in the study and simulation of insect swarms.
Associative Generation	The design and its alternatives are created by first specifying the relationship between the various components that will comprise the design and then assigning and alternating the values of specific attributes amongst each other.	One of the most common generative systems and the most recent advancement based on associative generation or associative geometry is parametric design (PD). The basic principle behind the parametric design is that the values of many variables vary, generally associatively, in response to diverse input parameters.

Accordingly, the research will focus on the evolutionary design systems; the final alternatives are the most suitable for urban morphology elements. The system provides many alternatives and is combined with another system, such as the parametric design in associative generation systems. Lately, Genetic algorithms have spread widely; the research results on Scopus -in the engineering field- with "genetic algorithm'" and "urban'' 2019 types of research, includes 1632 pieces published during the last ten years. While the research results on Scopus with "Shape grammar" and "urban" are 79 research, and with Cellular automata " and "urban" are 469 research.

3. THE APPLICATION OF GENERATION SYSTEMS IN URBAN MORPHOLOGY FIELD

A variety of studies have been carried out to generate urban morphology. This paper introduces fourteen highly cited studies to analyze the generation process and strategy. The selected papers are the latest published paper in the last ten years. Moreover, these papers are the most integrated with urban morphology issues, which includes more than generation objective (spatial, functional, climatic, social, coast) or generates more than one urban morphology element. Accordingly, these papers are dealing in deep with urban complexity issues. These studies will be compared to highlight the familiar and different aspects of the generation process. The comparison is based on comparing generation's systems, generation objective, used software, generated urban morphology elements, and case study location as shown in **Table 2**.

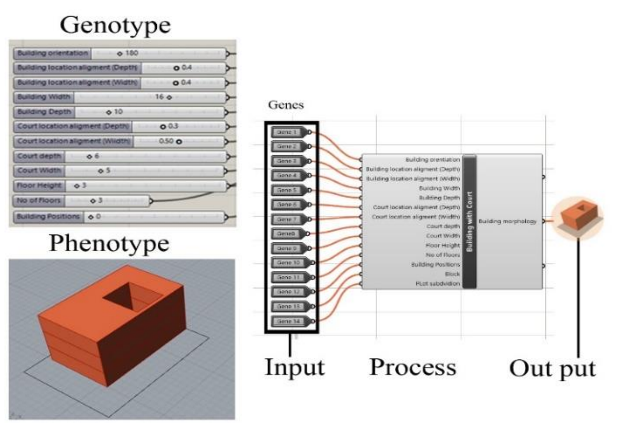


Figure 2: Explaining Genotype and Phenotype represtation (By researcher)

Table 2: Generation systems in urban

Author	GS	Objective	Software	UM Elements	Location year
[21]	PD	Spatial	Decoding spaces Grasshopper3D	Street Network Street Blocks	2012
[19]	PD	Functional	Grasshopper3D	Streets Plots Blocks	2017
[20]	EMO (GA)	Spatial	Decoding paces	Street Network Street Blocks	Ethiopia

	PD	Functional	Grasshopper3D	Land Use	2017
[22]	PD	Spatial Climatic	Blender 7.0	Street Blocks Open saces	Egypt 2017
[23]	PD	Climatic	Rhino grasshopper Ecotect Autodesk Flow	Street pattern Urban Blocks	Albina city 2017
[12]	EMO (GA) PD	Spatial	Decoding Spaces- Grasshopper3D	Streets Plots building	Cape Town 2018
[1]	EMO (GA) PD	Climatic Cost	-----------	Building	Netherlands 2018
[15]	EMO (GA) PD	Spatial & functional	Decoding Spaces- grasshopper	Streets Plots building	Germany 2019
[25]	EMO (GA) PD	Climatic	Grasshopper, Galapagos ANSYS CFD	Building	UAE 2019
[26]	PD	Climatic Functional Spatial	Esri City-Engine, rhino Grasshopper, Envi-Met Ladybug, Honeybee, decoding spaces	Building typology	Vienna 2019
[18]	EMO (GA) PD	Functional Climatic	Grasshopper3D CFD Wallacei_X	street networks building blocks	2020
[16]	EMO (GA) PD	functional socio-cultural Spatial Climatic	Wallacei_X Ladybug Decoding Spaces Grasshopper3D	Streets Pedestrian paths open spaces Plots building	China 2020
[17]	EMO (GA) PD	functional Social Spatial Climatic	Octopus-decoding spaces toolbox-ladybug-open FOAM Grasshopper3D	street network Block arrangement building volumes	Vienna 2020
[24]	EMO (GA) PD	Climatic functional	Grasshopper Ladybug, Butterfly, honeybee, Galapagos and Open FOAM.	Building block Open spaces	China 2020

There are several objectives to the generation process; three primary objectives are climatic, functional, and spatial. In addition, the social dimension considers the secondary objective in the generation process. Streets and buildings are the most commonly acknowledge elements in the generation process; pedestrian pathways are largely overlooked. The most popular engine in a generation is Grasshopper. Ladybug and Table 2 Generation systems in urban morphology studies. Honeybee are employed to simulate the environment in objective climatic studies. Finally, decoding spaces is the most helpful plugin for objective spatial investigations.

4. GENETIC ALGORITHM

Recently, genetic algorithms have had a wide application in several fields to solve a specific design problem. A Genetic Algorithm (GA) uses programming languages to find the best solutions automatically across the design variants [1]. Architectural form-finding was the first field to use genetic algorithms in morphological applications [3]. GA and genetic programming are evolutionary techniques based on natural evolutionary processes to find solutions that optimize a fitness function [9]. The main objective of evolutionary systems used exploratory engines to generate many solutions based on genetic algorithms [3]. Besides, it can find several best solutions that fit design specifications. In 1975, the book "Adaptation in Natural and Artificial Systems" considered the base of a genetic algorithm, where Holland introduced his concept of genetic algorithms. He defined GA as a heuristic technique based on the "survival of the fittest" idea. As a result, GA was discovered to be an effective tool for solving search and optimization issues. A solution is a potential contender for the optimum solution to an optimization issue [27].

4.1. Genetic Algorithms Terminology

Several genetic algorithms need to be clarified. **Table 3** defines several definitions used in genetic algorithms. Several urban morphology process definitions will be

Terminology	Definition
Gene	Gene is defined as the smallest unit of a genotype. Alleles are alternative forms of genes.
Genetic codes	Numerals or alphabet letters are used for coding in a genotype.
Genetic description	This genetic description can then be subjected to the genetic operations employed in evolutionary systems.
Genetic structure	Genetic structure is defined as A set of genes with a specific order or relationship.
The search space	All the available solutions are represented in a space called search space, which allows the area to find the solutions
The solution space	The real solutions are represented in space called solution space

illustrated in **Figure 3**. Then, the generation process will be explained in the next part. The generation process includes input, process and output. In genetic algorithm science the input named genotype, and the output is the phenotype. Each individual has a genotype and an identical phenotype. Phenotypes represent the physical description of a population. Phenotypes are controlled by several parameters from their final appearance (distance, length, width, height, etc.). The coded versions (numerical, shapes, etc.) of these phenotypes are genotypes. A coded parameter can be described as a gene [14], as shown in **Figure 2**.

Table 3: Genetic Terminology [9;14]

4.2. Genetic Algorithms process

Like natural evolution, a Genetic algorithm (evolutionary design) seeks to find the best solutions for a specific problem. This algorithm develops many solutions simultaneously, hoping to achieve the objective function. The algorithms depend on assigning several populations in search space; then, it evaluates its fitness. Afterwards, the

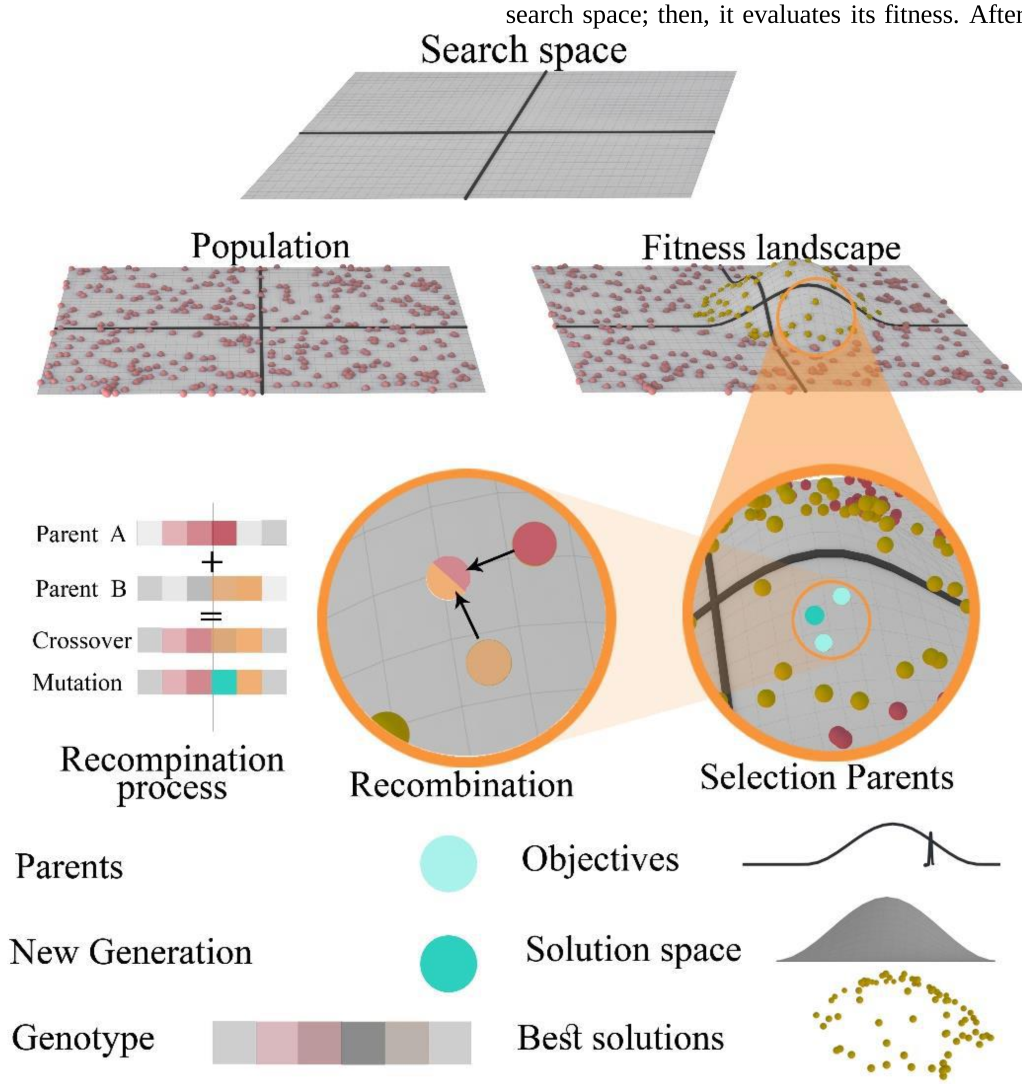


Figure 3: illustration of genetic algorithms essential definitions (by researchers)

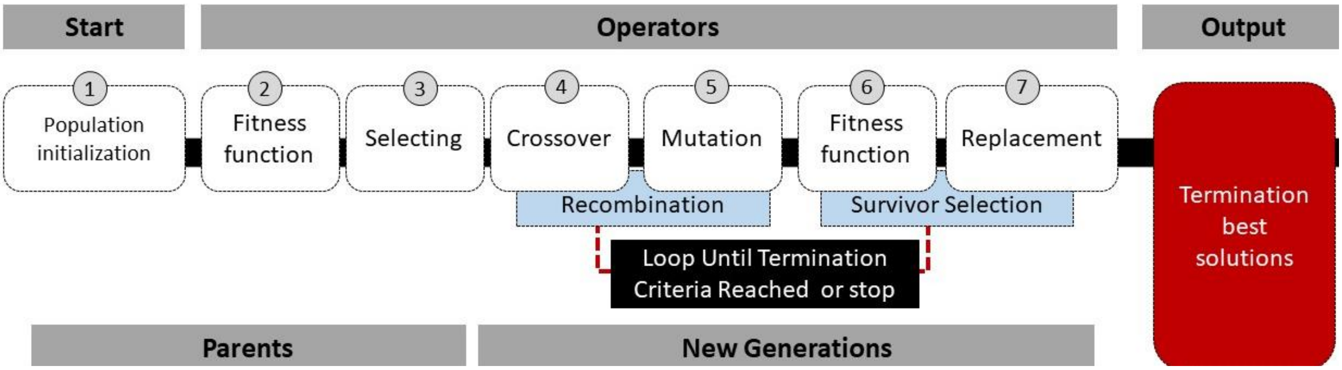


Figure 4: Evolutionary Optimization Research process, Drawn after [27].

highly fitted solutions have a great chance to be developed in the next generation. The fitness function is a gate that allows the fittest solution to crossover depending on how well the solution meets these criteria. Fitness values are frequently displayed in search spaces, resulting in mountainous fitness landscapes, with a high peak corresponding to solutions with optimal finesse in that region of the search space [14]. The search process is a continuous loop evaluation of the produced phenotype. The process aims to find the optimal solutions which fit the generation objective [28].

4.2.1.Population

The term "population" refers to a group of people. A population comprises the people being tested, their phenotypic characteristics, and some information about the search area [14].
This initialization is suggested for covering the whole solution space at random or modelling and incorporating expert knowledge. Finally, the presentation determines the startup procedure.

4.2.2. Fitness Landscape (evaluation)

The fitness function is the process evaluate several solutions to indicate the best solutions. The best solutions are the most fitted solutions to the objective functions [29].

4.2.3.Selection Parents

This process aims to filter the populations to select the most suitable parents for the next step depending on fitness values [27].

4.2.4.Recombination

The parents are picked at random by the reproduction operator. At random along the string length, a cross-site is selected [27].Recombination is an essential process for evolutionary systems. This process selects two populations (father and mother) with good qualities and characteristics then combines their genes to produce the next generation [28]. **Crossover** is a process of merging the genotype of two or more parents. A famous one for bit string representation is n-point crossover [27]. **The mutation** is the process of randomly changing the series of genes; the mutation rate is the rate of change between genotype values in search space [29].

4.2.5.Replacement

To ensure the quality of the population distribution in the search space, the population is distributed randomly to cover all the research space. Then, the replacement process is carried out to ensure that the solution space was covered efficiently. This process starts when the population converges towards the optimal space.

4.2.6.Termination

The limits of termination process loops are defined at the beginning of the analysis; the number of populations and generations must be limited to ensure that the most suitable alternatives are generated promptly.

4.2.7.Experiments

The experiment stage is considered an essential process. It has been proven that the experiment has an essential role in upgrading research topics related to genetic algorithms. It also prevents output results from being skewed by some researchers [27].

5. CASE STUDIES

At this process, the research introduces five case studies to be analyzed. The research chooses the latest studies, which have been published between 2019 and 2020. The selected cases are multi objective studies, which means that the optimization process includes more than one type of objective such as social objectives and climatic objectives or social objectives and functional objective.

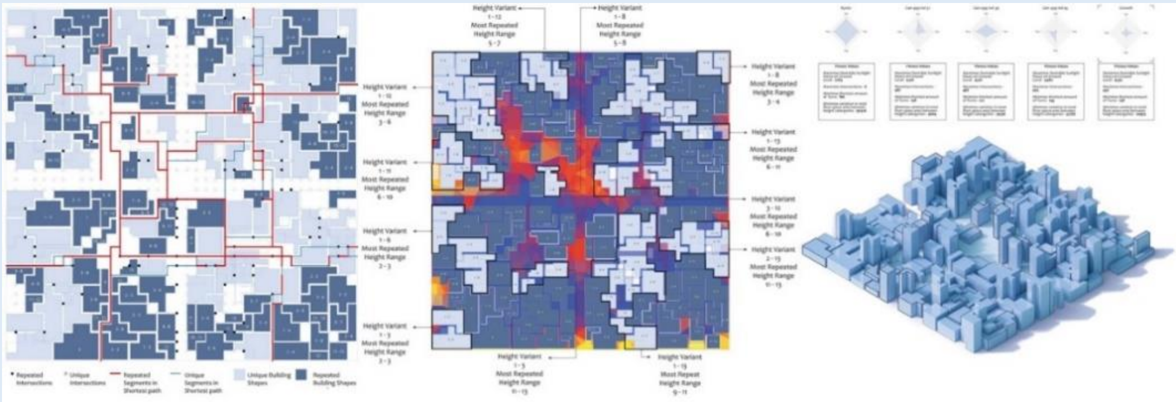
5.1. Case one by (Koenig et al., 2019)

Table 4: Case One [15]

GDs	(EMO) algorithms - parametric Design	
Objective	The research aims to represent the urban morphology elements in a new flexible data structure. Generating urban morphology using a methodology combines the art of urban analysis and EMOs.	
Limitation	The research divides the generation process into two phases in order to facilitate the generation process.	
Strategy	Generating parametric model	The new data structure saves the data of the parents, such as: The streets data structure includes segment length, the angle between segments, and the connectivity index. Block data structure includes street segments. Building Model includes three distinct building types per parcel.
	Optimization Strategy:	Optimization Strategy is based on ES and PISA framework's hype algorithm. .
	Design variants.	Variations are presented in several urban morphology elements such as roadway segments, plots, and buildings.
Case study	Center of Weimar, Germany	
Process	In put	Land boundary and connected streets
	Streets	**Optimization of streets:** Four goals are for roadway optimization: Decrease network streets length. Increase the values of Betweenness certainty. Increase the area of the buildable plots. The street network should be orthogonal as possible. **Evolution of streets:** Space syntax is used to analyze streets certainty. Building
	Building	**Optimization building:** this process is controlled by building forms and height as parameters. Two objectives have to be achieved: Increasing the floor area ratio (FAR). Decreasing the building heights. **Evaluation Of building:** several urban morphology indicators have to be calculated, Such as floor area index, gross area index and street density.
	Out put	Output includes two types of data (200 literation for each one) spatial configuration of streets network with block percolation and building typology.
The results	It has been considered that the system to be a cognitive urban design computing approach.	
Software	Grasshopper, Rhino3D, decoding spaces-Toolbox.	

5.2. Case two by (Choi et al., 2020)

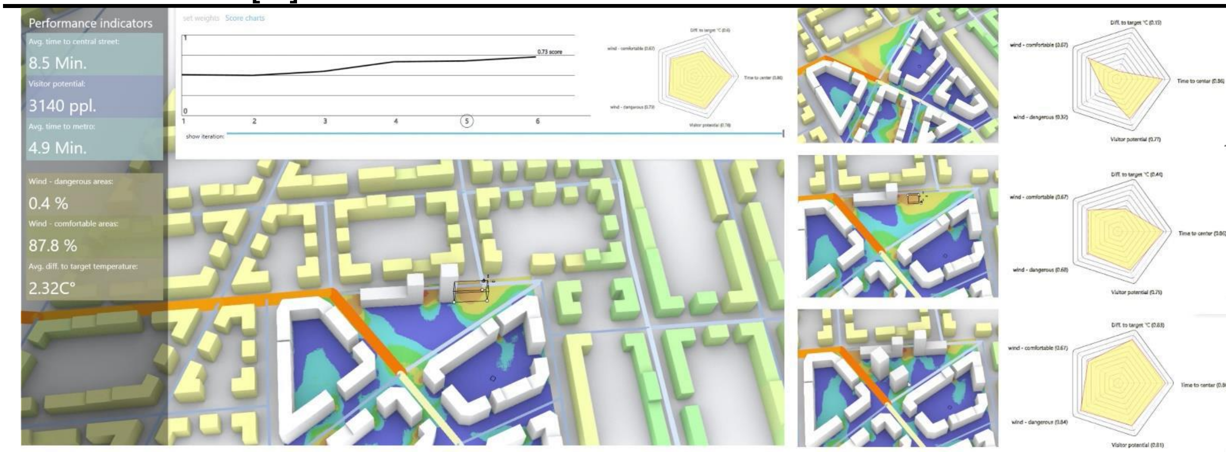
Table 5: Case two [16]



GDs	EMO & Parametric Design	
Research objective	Translate socio-cultural properties into quantitative data sets that define the morphological characteristics of the urban tissue.	
Limitation	Study limits the available type of urban morphology, it depends on super block as parametric model. The research extract the concept of the used parametric model from site typology and history.	
Strategy	The research strategy used three integrated type tools.	
	Manual	Three stages have been done manually: Parametric model set up. Microclimate conditions and socio-culture characteristics analysis. Indicate the most suitable fitness objective.
	Semi-Auto	Comparing between final results of the alternatives analysis. Using Pareto front to indicate the most suitable alternative.
	Auto	Generation optimization Application (EMO) By Wallace X grasshopper.
Case study	Kyoto, Shijo-Karasuma, Japan	
Projective objective	Generating an urban superblock adapted with city grid and building density. The superblock have to enhance pedestrian conditions (alleyway connectivity-sun exposure).	
Process	Evolutionary matrix	The matrix includes Four objective functions: First, increase sun exposure at ground level. Increase alleyways connectivity. Decrease the number of turns in the shortest path. Decrease the variation in the unit's ground floor areas
	Parametric model	The model is consist of four superblocks 120m*120m. Each block includes six entry points at each side connected; these points were connected by grids represent pedestrian paths.
	Evaluation	The distance between grid points (represent streets) and block entry points are calculated to indicate the two shortest routes.
	Analysis	Four aspects have been analyzed such as: The spatial configuration values for the streets network were calculated by space syntax. Solar radiation was analyzed for superblock using ladybug. Land use distribution was analyzed to locate commercial, mixed-use and residential groups. The visual connectivity between buildings and open spaces were analyzed.
	Initial Selected solution	In order to get the most suitable solutions, the solutions with the typical characteristics as building shape and FAR are selected initially.
The results	The optimization results were 26 variations in the Pareto front.	
Software	Wallacei_X , Ladybug, Decoding Spaces ,Grasshopper 3D	

5.3. Case three by (Duering et al., 2020)

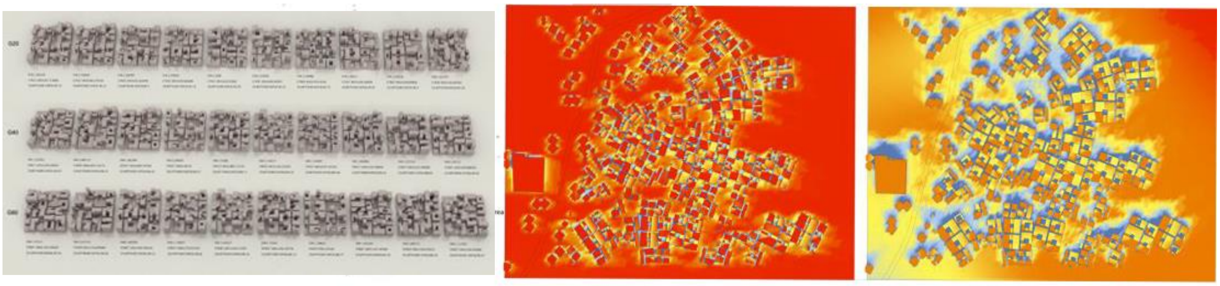
Table 6: Case Three [17]



GDs	Parametric Design- Genetic optimization engine	
Research objective	Optimize real-time urban morphology through an integrated framework that includes several simulation techniques.	
limitation	Choose closed blocks as a a parametric model.	
Strategy	Use the opportunities of deep-learning techniques in real-time to analyze the microclimate parameters side by side with graph-based mobility and accessibility models.	
Case study	An urban design intervention in Vienna.	
Projective objective	Providing around 600 residential units. ▪ Promoting walkability of the whole area. ▪ Enhancing the integration to the surrounding. ▪ Process	
Process	In order to achieve the final optimization, all the parametric algorithms are connected through a loop to maximize the performance of a design.	
	Generative Model	The model includes street networks, land blocks, building blocks, and open spaces.
	Evaluation	**Accessibility:** is calculated by a multi-modal graph network, which includes the site grid and surroundings grid. **Microclimate:** thousands of times of analyzing solar radiation and wind flow has been done for different building heights. The analysis results have been saved to the model using deep learning techniques.
	Optimization	The optimization process used the Octopus EO engine. This engine is suitable for multiple fitness objectives.
	The Parametric Model	The parametric model includes three urban morphological elements such as streets grid, Bridge, and building. Each element includes its parameters as: Grid: rotation angle of a guiding street segment in the middle of our project site. Bridge: Four possible locations for another railway overpass are preselected. Buildings: an open perimeter block typology for the building generation.
	Evaluation	In this stage, several optimization objectives are achieved by measurable performance metrics in the computational model.
Results	The quick analysis of the urban morphology helps to take several design decisions in a short time. Thus, this application achieves the maximum benefit of the genetic algorithm in the practical field.	
Software	Octopus-decoding spaces toolbox- ladybug- open FOAM -grasshopper	

5.4. Case four By (Zhai and Riederer, 2020)

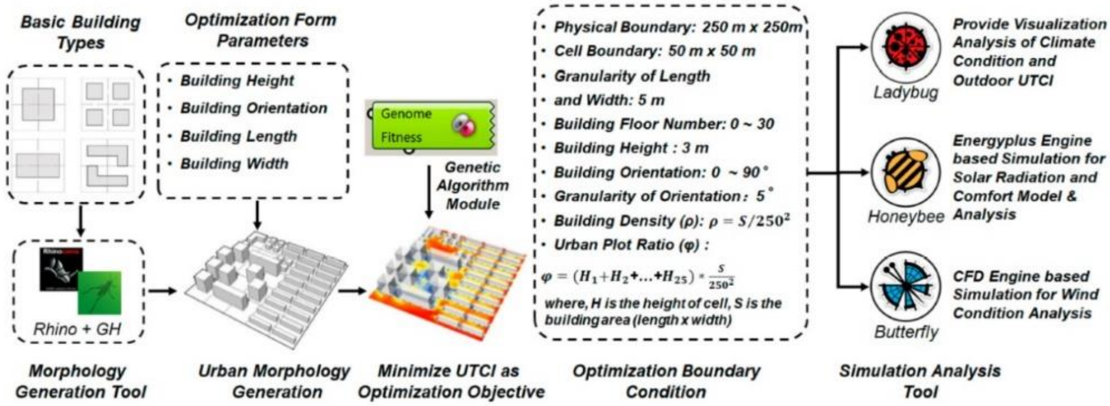
Table 7: Case Four [18]



GDs	Evolutionary multi objective optimization	
Research objective	Expanding the application of e evolutionary design in urban design.	
Limitation	The area topography decreases the flexibility in controlling street dimensions and network hierarchy during the generation and adaptation process. The research extract the concept of the used parametric model from site typology and history.	
Strategy	The strategy consists of two experiments to solve the complexity of urban morphology generation with conflicting objective criteria.	
Case study	Fez el Bali, Morocco.	
Process	Urban Modeling	The parametric modelling generates block dominance in two scenarios: The first scenario aims to study the relationship between the program, land use, density, and the plot (dimensions-geometrical configurations). The second scenario aims to study the relationship between the typological nodes and edges of the street network.
	Computational experiment	The project site includes many constraints such as: Vernacular housing is a complex morphological pattern. In addition, the dense site of the project includes both touristic needs and industrial needs. Increasing the floor area ratio is a necessary objective. Slopped site with 66.6 m difference between site levels. 'Deep canyon' streets and blocks are necessary for self-shading.
	Exp 1 - Single Block	**Parametric model:** the first stage uses a square urban block (20 m) that includes four closed building blocks. Urban morphology genotypes are Floor number, street width, courtyard ratio, and room divisions. **Fitness Objectives:** Maximizing Floor area ratio and street area, and direct sunlight exposure. **Evaluation:** Gives further information about the degree of variance and the optimization's overall trend.
	Exp 2 - Urban Block in Context	**The parametric model:** targets the generation of superblocks and street network generation. **Genotype:** The super clock consist of a sub-block and secondary network. **Fitness Objective:** enhancing land use distribution and building diversity. **Output:** The Genetic algorithm-generated result of 1000 solutions (10 individuals x 100 generations)
Results	Comparing the two different urban systems in Fez el Bali, the modern urban structure Nouvelle Ville shows no relation to the Medinas urban strategies. The application of the genetic algorithm has a positive effect on the quantitative fitness values. However, the design variation is still complicated because of the significant number of parameters used in the generation model to cover all possible solutions.	
Software	Grasshopper, CFD simulation program, Wallacei_X	

5.5. Case five by (Xu et al., 2019)

Table 8: case five [24]



GDs	Parametric design, Genetic Algorithm	
Research objective	Research objective Enhancing Outdoor thermal comfort using a parametric model includes (building form, height, and street orientation).	
Limitation	The diversity of actual urban forms led to the use of specific types of building forms. These types are extracted from the actual block.	
Strategy	As mentioned before, the researchers select three parameters to be used in the optimization process. First, the process aimed to decrease the Outdoor thermal comfort index.	
Case study	Kashgar, China in a dry and hot region,	
Process	Parametric model	**Generic Building Form** The study builds the urban morphology based on four types of buildings. Each type is distributed differently (pillar 1-mass, strip 1-mass, dot 4-mass, and courtyard 2-mass).
		Ideal Block Generation: the study uses a regular grid to subdivide the area into buildings and open spaces. Any building with zero height is considered open space.
		Actual Urban Block: The area is divided into five squares in the two directions (70m*70m)
	Optimization	Use ladybug tools in the optimization process.
	Analysis	Model Setup and Weather Conditions The analysis of weather conditions in several buildings morphology is set up to calculate microclimate conditions in several cases.
		Comfort Index The analysis calculates the values of predicted Mean Vote (PMV)
Results	The study highlighted that several urban morphological parameters and indicators are essential to enhance outdoor urban climates, such as street orientation, Sky visibility coefficient, building height, and open space layout. Climatic Indices that two factors (Mean Radiation Temperature and Solar thermal radiation) have the dominant role in controlling UTCI values. The generated urban morphology achieves stable wind speed 3 m/s, and the best optimized UTCI is 27.43 C.	
Software	Rhino & Grasshopper platform, plugins Ladybug, Butterfly, Energy plus engine, honeybee, Galapagos and Open FOAM.	

6. COMPARISON STUDIES

The comparison study will fi=focus into two points: tools and techniques, and Generation Objective, as shown in **Table 9.**

Table 9: Genetic Algorithm application In urban morphology

Cases	Genetic Algorithm application In urban morphology	
	Techniques and tools	Generation Objective
Case 1	**Parametric model:** proposed a new tree structure used to represent urban morphology elements in the hierarchy. **Optimization process:** a combination of Evolutionary system with Hype algorithm..	**Street system:** Shorten street length, maximum street Betweenness centrality, maximize buildable area by orthographic streets configuration. **Building:** Maximize floor area ratio (FAR).
Case 2	**Parametric model:** convert the socio-culture properties in quantitative data in the parametric model. **Optimization process:** mix a method using automatic, semi-automatic and manual steps.	Increase solar radiation access to ground level, Increase the number of pedestrian walk paths, and Decrease the number of turns through the shortest path. Minimize building floor area ratio according to building height and connect building height to street segment length.
Case 3	**Optimization process:** integrated multi-engine in one framework, which combines deep learning and real-time analysis in the generation process.	Improve site accessibility. Enhance microclimate Promote walkability
Case 4	**Parametric model:** Simplify the complexity of the urban generation process by determining dominant block scenarios.	Maximize streets area, Maximize FAR Increase solar access to the courtyard Generate urban patch, which addressed the issue of land use
Case 5	**Parametric model:** A parametric model depends on the ideal block and actual block to facilitate urban morphology generation.	Enhancing thermal comfort by decreasing UTCI.

The previous table compare between five case studies, the research finds four major applications. The four major application of genetic algorithm in urban morphology generation:

- Enhancing micro climate conditions.
- Promoting walkability through urban morphology.
- Achieving several functional needs.
- Increasing site accessibility.

7. DISCUSSION

The research discussion can be divided into three parts, several applications in genetic algorithms in urban morphology generation, extracting the constraints, which limits this application, and indicating the gaps in this field of study, as shown in **Figure 5**.

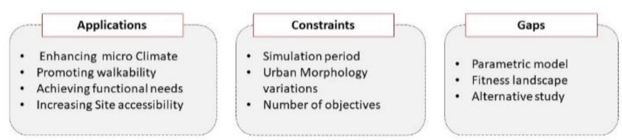


Figure 5: Genetic algorthims applications, constriants and gaps in urban morphology generation (by researcher)

Genetic algorithm Applications in urban morphology generation:

After analyzing several cases, the research outline four dominant applications. Enhancing microclimate is the first application. For example, It includes solar access and radiation, as mentioned in cases two and four. Besides, achieving thermal comfort is the main objective of case five. The second application promotes walkability, as in case one, aims to shorten the street length and achieve orthographic streets configuration. Case two aims to increase pedestrian walk paths, and decrease turns number. The genetic algorithm can achieve functional needs as floor area index (FAR) or gross area index. Case one and case four targets to increase (FAR), and case two targets to decrease (FAR). Case four aims to enhance land uses distribution. The final application is to improve site accessibility.

Constraints of genetic algorithms in urban morphology generation:

The research indicates that three constraints limit genetic algorithm applications in urban morphology generation. The first constrain the simulation period; the simulation process depends on machine processors' performance and analysis engines used in the algorithm two take more than forty hours to finish the simulation, case three analysis several alternatives before. The analysis data is used by artificial intelligence as an input in the process to get real-time results. One of the main objectives of genetic algorithms is to generate many variants. The complexity of urban morphology is imperative for the researcher to simplify the parametric model (genotype). For example, case two chose superblock and fixed its outer dimensions to be used in the optimization process. Case three depends on six closed blocks; case four introduces two sceneries in urban morphology generation, each scenario generated individually with a different objective. Case five introduces the concept of the ideal and actual block to simplify the parametric model. Almost parametric models are inspired by location history and typology. Accordingly, urban morphology variations are the second constraint. The third constrains the used objectives; many objectives in the fitness landscape process require a long simulation time. Accordingly, researchers prefer to neglect some objective to achieve their research aims. The nonelection process is conflicting with the primary objective of using genetic algorithms to generate complex urban morphology.

The studies gaps specialized in the usage of genetic algorithm application in urban morphology generation:

During the process of urban morphology generation, the research indicates three main gaps to be held in future studies. Case one author's main objective is to update the data tree (data structure sequence in grasshopper) in the parametric model. Our research authors propose using international codes related to urban communities as a genotype in the parametric model. Besides, we proposed to use the urban morphology indicators also as a genotype. The second gap locates in the fitness landscape process; the research finds that social qualities in urban morphology such as enclosure, legibility, and human-scale have to be used as an objective in the fitness landscape. Almost all studies focus on the parametric model, analysis, and optimization process. The generated alternatives need more studies, such as case five, which compares several alternatives' morphological elements and indicators with UTCI values. The researchers must focus more on the relationship between the final alternatives and performance (environmental, social, etc.).

8. CONCLUSION

Many studies focusing on mathematical modelling of either ecological and social objectives to generate morphological relationships of physical forms of cities and urban tissues, such as overall shape, compactness, and density, or quantification of energy, information, and material flows, as well as their associated networks, continue to grow the literature on city complexity studies. In addition, there have also been various quantitative evaluations of existing cities and conurbations.

The first step in constructing genetic design algorithms for urban science is to understand the generation logic and embryological processes that lead to the morphogenesis, variation, and dispersion of all organic entities. Genetic algorithms are iterative techniques that are commonly used to tackle non-linear and intractable problems. They are based on simplified logic abstracted from generation. As a result, they may develop static and dynamic architectural and urban forms iteratively based on social and ecological objectives on a parametric model to reach an optimum design.

Research has *presented a theoretical review of generation systems and* highlighted the role of genetic algorithm urban morphology generation. At first, research explains the theoretical base of genetic algorithms (evolutionary systems). Then, it collects fourteen case study (use generation systems) in urban morphology generation and introduce the generation objective, used software, generated urban morphology elements, and case study location. Moreover, the research analyses the generation limitation, generation strategy, generation objective, generation process, and generation results. Afterwards, the research compares the five-case study to extract the several applications of genetic algorithms in urban morphology generation and several used objectives. Finally, the research discusses three significant points about the application of the genetic algorithm in urban morphology. First, the constraints, which limits the application of the genetic algorithm in urban morphology, the research highlighted the gaps in this field of study.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT:

Mostafa M. Elzeni: Generating the idea, Collecting data, Methodology & Original draft preparation, **Ashraf A. Elmokadem:** Reviewing & Supervision, **Nancy M, Badawy:** , Methodology ,Validation, Editing, Reviewing & Supervision.

DECLARATION OF COMPETING INTEREST:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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