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A User-Centric Approach to Optimize Visitor's Experience in Exhibition Spaces Using Parametric Spatial Analysis

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Abstract

Being the main user of any architectural product, the user's role in the designing process should be significant, especially in complex spatial spaces such as hospitals, museums, offices, and public-use buildings. This gives the users meta-roles such as communicators, performers, and interpreters.

User-Centered Design (UCD) tries to optimize the fit of the spaces with how users can, want to, and need to use in these spaces, rather than forcing the users to change their behavior to accommodate the architectural spaces or designing dysfunctional spaces. Such spaces were designed neglecting the human factor and only using building regulations.

The visitor's parameters, profiles, spatial experiences, and the architectural configuration are what can affect the experience in architectural spaces.

This paper explores a different UCD (user-centered design) approach in the evaluation of the built environment which is the parametric spatial analysis approach. The approach studies the spatial pattern of human behavior of a random selection of users, so it could represent any potential users in the buildings. Aiming to intensively engage users in the design process, the approach uses parametric spatial design in analyzing the visitor's behavior and deducing some design patterns and configurations that focus on different ways of user's engagement. This approach compares the definition of users, their roles, and the type of space envisioned and produced as well.

This paper describes an approach that attempts to bridge the gap between parametric geometry modeling and methods for measuring the spatial properties of this geometry.

In exhibition spaces with their different spatiality, visitors tend to have some indicators which can be measured. Accordingly, designers create functional spaces that suit the different types of visitors using parametric components that study the collective human behavior (organizational behavior). These functional spaces are designed through observation, user surveys, and interviews to simplify the complexity of decisions regarding the design process and visitor's parameters, and to embed them into an algorithm that can solve the complexity of the visitor's parameters.

Analyzing visitors' behavior and the spatial morphology improves the visiting experience and provides better interpretations. The analysis makes the designers aware of visitors' circulation, visiting styles, behavior, patterns, tendencies, and trends within a wide diversity of spaces. Moreover, this analysis can be combined into an evolutionary algorithm to help solve problems.

Keywords

Visitor's parameters; Parametric spatial analysis; Optimization

1. Introduction

Human aspects help define the perfect space for each individual, that explores and captures the immaterial, human needs of a space, like personality, values, experiences, ritual and time.
Visitor studies explore human experiences within any architectural spaces such as museums, cultural heritage sites and other informal learning settings to inform decisions is greatly affected by the spatiality and decisions made in the spaces.

Spatial layout planning, especially designing exhibition spaces and patterns of circulation for a planned efficient navigation and orientation and for a better experience for the visitors who are the main user of the architectural product, is one of the most complicated problem in architectural design as it has many parameters that should be tested and figured out.
By examining the extent to which spatial structures can be optimized using the concept of evolutionary strategies, which search for solutions for spaces by systematically varying the parameters and choosing a certain goal (Fitness Function).

Parametric modelling combined with optimization algorithms has emerged as one of the most widely used computational methodologies for spatial and experiences design allowing designers to script complex generative algorithms for design space exploration.

1.1. Architectural Space

In architecture, design begins by generating ideas and continues by transforming them to concrete spatial formations and spaces that are functional and fits the users. Architects learn about the design problem by creating alternatives and testing them in order to gain desired spatial formations. A comprehensive architectural knowledge helps architects in this process. This knowledge is a synthesis of practice and theory, experience and research. Architects must proceed in to bring all parameters together in a creative way.

1.2. Design Complexity

Utilizing a large repertoire of organizational patterns and design precedent knowledge together with the precise criteria of spatial evaluation can present design challenges to make sure of using the human factor and creating functional spatial formations so it needs theories and applications of implementation of a parametric design process. There is an opportunity to supplement the designer's knowledge with computational decision support that provides real-time spatial feedback during conceptual design. This paper presents an approach based on a generative multi-performance framework, to configure and optimize architectural designs based on a precedent design.

2. Parametric Modelling

The introduction of Parametric Design has turned up a new flexibility in discovering solution space, setting up the way for geometry customization and the form optimization system.

It helps in creating and exploring the parameters to evaluate the designs and help the designer from the beginning of the design process to get the best design outcome among a large number of opportunities and easily tested and modelled and evaluated to achieve a performance oriented design.

Generative algorithms have also been used to define the optimal user accessibility and visibility in architectural design and so analyzing user movement, the behavioral patterns and spatial accessibility of visitors. The whole optimization process can be developed as a Rhino Grasshopper script.

Grasshopper is an advanced parametric modelling tool which is working with Rhinoceros interface. It is an influential design tool which allows exploring a new affiant way of design. The geometry in the grasshopper is defined by using graphical interface without having any knowledge about scripting language. The geometry will be created by dragging and dropping available components, in which these components represent data, function in the working.

2.1. The Parametric Models

Grasshopper consists of two main types of objects which are "parameters" and "components". Parameters are used for to input variables and feed them into Components that transform them and output the results. In which the inputs may be geometry or a single data
Using Rhino/grasshopper in this research is to create geometry or building which is able to change its elements parametrically. A parametric or generative model is an essential feature in the optimization process.

2.2. Optimization Process Using Evolutionary Algorithms

- Design Variables: The mathematical expression or any quantity that controls the shape of design and its configuration such as height, width and height. These variables are controlled by designer or some geometrical equation.
- Design Objectives: are that designers try to achieve, such as those functions which designers try to maximize or optimise.
- Parameters: are quantities that affect the design objective but are considered fixed, so they cannot be changed by the designers
- Constrains: the limitations of the design space in which characteristically happen by reason of finiteness of source or technologically limitation that the designer set to their targeted designs.

2.3. There are Two Types of Optimization:

- Single-Objective Optimization: when the design problem optimizes a single objective, which mostly maximize or minimize. Therefore the optimization model is scalar.
- Multi-objective Optimization: when the problem has more than one objective to optimize, the optimization model will have vector objective instead of scalar.

Optimization is an iterative process which starts with defined geometry, then the geometry will be simulated using a parametric simulation software with a simulation process, after that based base on the obtained feedback for the simulation engine, the geometry has to capable to change its parameters to get better simulation results in the next generation of a configuration according to observations or knowing the visitors behaviour and pattern to accommodate better visiting experiences and behaviors among the exhibition spaces or any architectural space.

3. Spatial Analysis

3.1. Space Syntax

Configuration is defined not simply as connections, but as 'relations that take into account other relations
Syntax techniques can simply be turned round and used in design as they are tools to think with and experiment with, as well as tools of analysis. Architecture is about the exploration of possibility and so are space syntax techniques. Given the working spatio-functional understanding provided by the analytic phase, the syntax model can be turned into design mode and simulate the configurational effects of different design ideas.
Space syntax is based on configurational theory of space and attempts to decode spatial formations and their

impacts on human activity. By the development of new techniques for representing and analyzing space, space syntax appears as a tool for architects to explore their design ideas and understand possible effects of their proposals by illustrating a link between research and design.
Parametric analysis can be used in the implementation of optimizing spaces and enhance the visitor's experience.

3.2. Accessibility

Accessibility analyses help in understanding socio-economic potentials of a place. And how visitors move along different spaces or see certain exhibit if they are accessible or there is a certain route that should be followed.

3.3. Visibility

People experience their environment mainly by vision. What they see influences their experience and behavior. Our advanced visual analysis methods help to:

- Identify visual attractors and visually prominent places
- Create navigation-friendly environments
- Estimate the visual impact of new developments

4. Simulation

Simulation can be able to predict the environmental and structural performances of the building. The power of simulation techniques and software depends on the performance of system to the modification that been done by designers. However, the main disadvantage of simulation programs is that they work under trial and error process. It means that designer has to have solution in order to get feedback for the simulation engine. Therefore, the design process involves recurrent possibilities, evaluations and adjustments to attain the desired results.
Simulations are considered a significant tool in the digital design process, particularly in the performance-based design. In which simulations feed the design process by helping designers to find, explain, and confirm through representations the achievement of desired solution. Yet the success of this process depends on the designer skills in the defining of design problem correctly, formulation of valuable hypothesis and most importantly to interpreter the alternative outcomes.
The link between parametric design tools and simulations-based designs are still indirect and needs more research that what we are discussing in this paper to find the linkage between parametric analysis and the evolutionary optimization for better results through the spatial design or the evaluation of spaces existed.

4.1. Spatial Analysis on Different Configurations

Studying an existing configuration and how the visitor's spatial analysis can change according to the spatial formations and accordingly the whole visibility and behavioral patterns, we can manage to reach the solid and reliable parameters that should be used in the design and evaluation process.

4.2. Existing Models for Spatial Analysis

Spatial configurations have been largely studied in architecture, usually utilizing computational methods for spatial analyses at building or urban scales. Creating diverse representations of the components of the space and their relationships.

These allow the user to script complex generative algorithms without prior programming knowledge and can help steering design space exploration. Exploring different solutions can be done in a timely manner as the parametric design process.

Complex environments constitute a compelling common ground for architects. However, Galapagos for Grasshopper for example yielding a single near optimal solution. As a result, parametric modeling as implemented in existing environments lacks of guidance features and design space exploration, usually remaining limited to manual manipulation of sliders and initiation of generations helping to solve the architectural process.

The manual observation by pen-and-paper direct observation methods are the most widely used for data collection of human behavior such as movement, occupancy, and interaction among persons and their visiting styles and behaviors . Researches have demonstrated strong correlation of building layouts and general human occupancy, movements and interaction among them helping to model their behaviour and reach norms of patterns. This paper reviews two components in grasshopper as parametric components, and they are:

- Smart Space analyzer
- Decoding Spaces

4.3. SmartSpace Analyzer Plugin

Is an intuitive tool to perform spatial analytics on a building or urban scale. It performs distance mapping, visibility analysis and connectivity analysis in seconds. As a Grasshopper plug-in for Rhino, SmartSpaceAnalyser provides real-time interaction in the modeling environment to quickly test a range of scenarios with instant visual feedback. It can come up with:

- Distance To: How far away is everything from one or more locations?
- Average Distance: What is the average distance to all locations from all locations?
- Visibility: What can be seen from my current location and any location the users may be in?
- Field of View: What is directly visible from my current location? What is in my peripheral vision?
- Walkability: Where can be walked in and how long and it is mainly used in urban spaces?
  The following is the smart space analyzer component and it can change to any of the previously mentioned results.

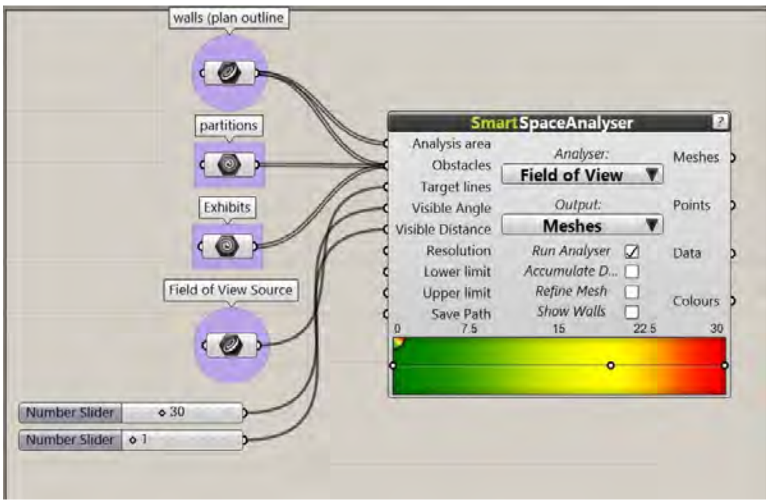

Figure 1. Field of view Component (Smart space analyzer)

By studying the existing configuration of Picasso exhibition in Cairo, Egypt and its plan and applying these parametric components it made it possible to analyze different spatial parameters that affect the user experience in spaces and what can affect the course of their visit to design a genetic component using generative tools to optimize the spatial complexity in exhibition spaces.

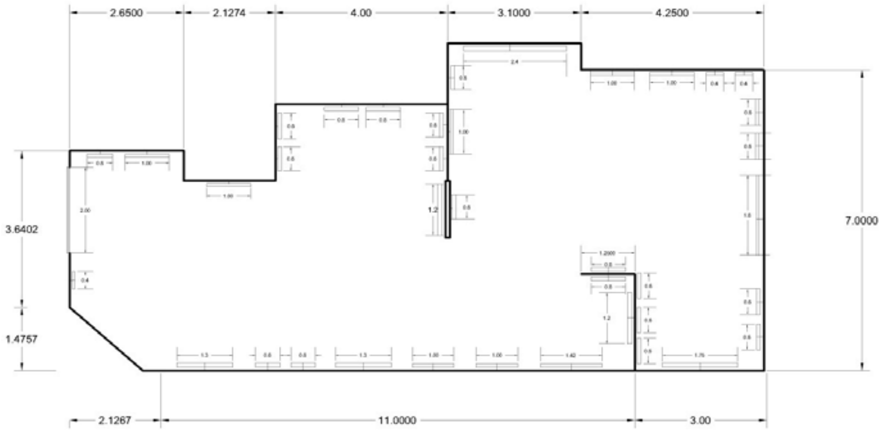

Figure 2. Plan of Picasso Exhibition in Cairo

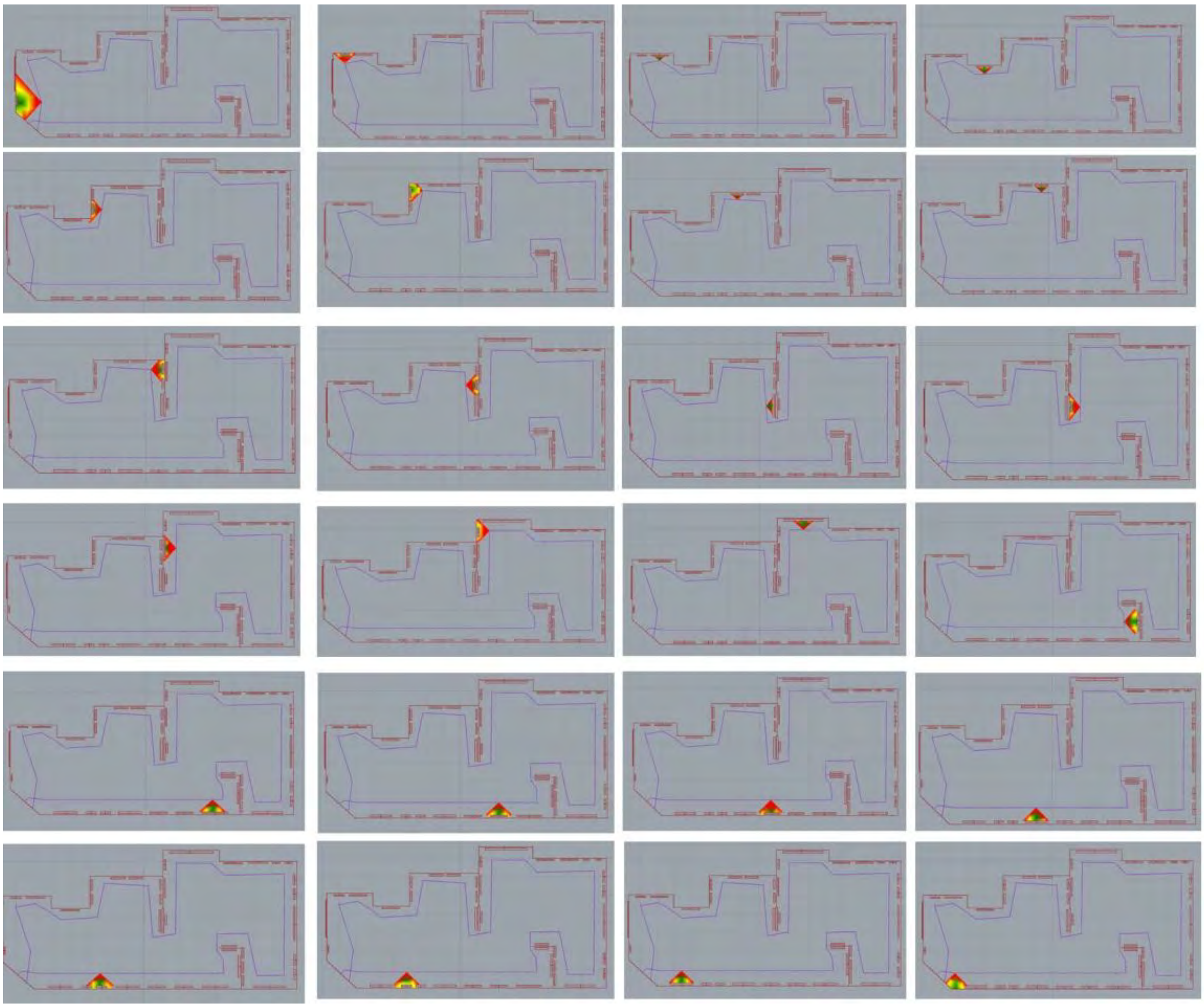

Figure 3. the parametric Visibility Analysis of a certain Visitor in the Exhibition using smart space analyzer plug in

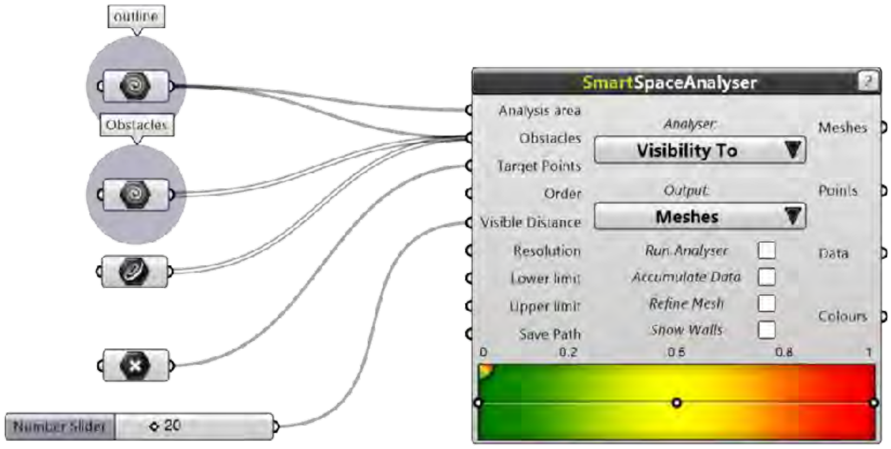

Figure 4. Visibility to Component (Smart space analyzer)

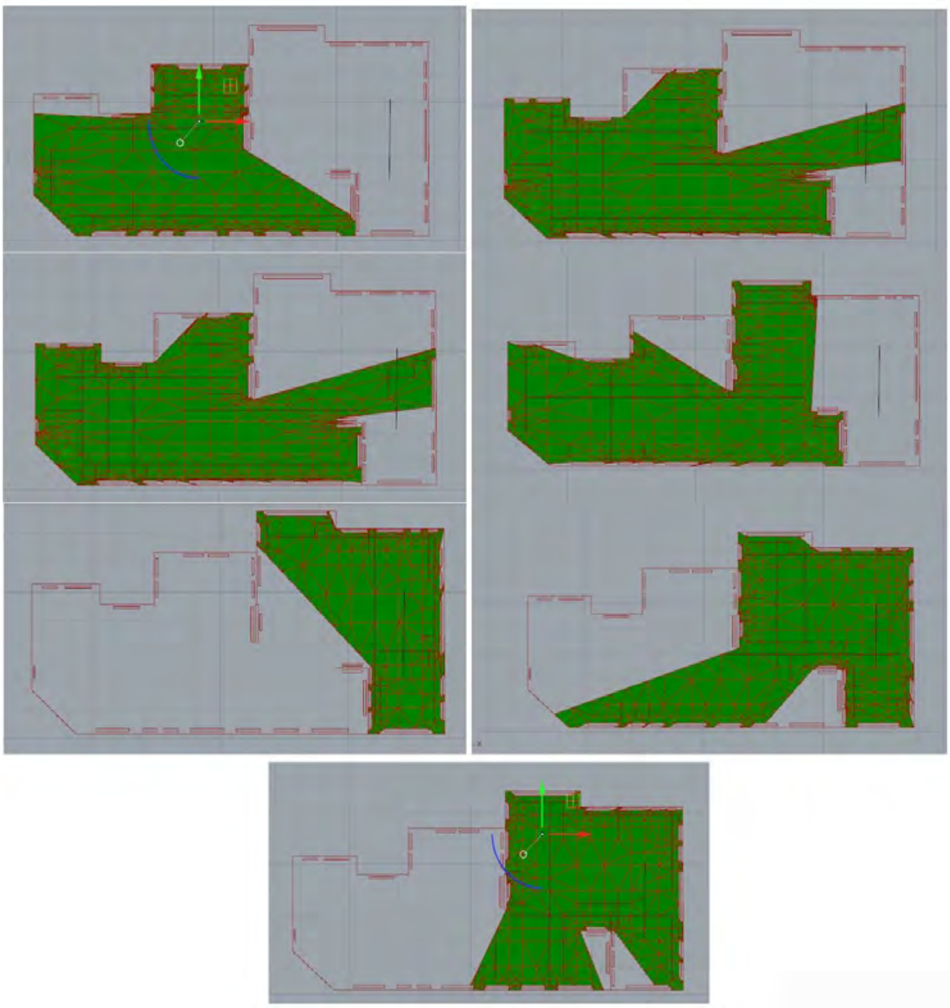

Figure 5. Visibility Analysis using smart space analyzer

4.4. Decoding Spaces:

This component is able to interpret segment maps from parametric line drawings for Evaluating Axial maps and visibility the analysis graphs can be related the directly visualization to the component parametric model, will be which extended opens up by new displaying ways of thinking here are images of visitor's (Cones of vision).
Isovisits from two different visitors in the space and the grey is their visual intersection to test the crowd visibility and the human behavior within a group or affected by other visitors.

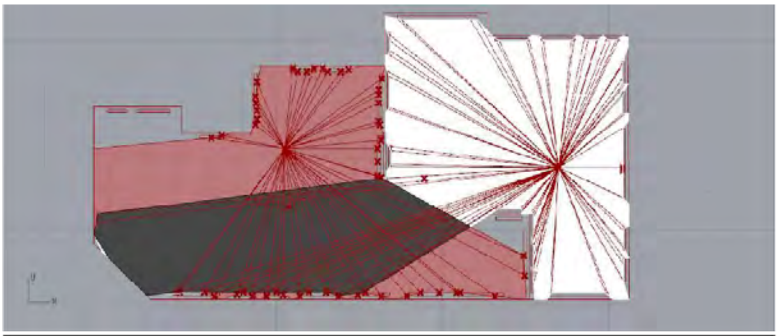

Figure 6. The intersection of two different visitors from Decoding Spaces component

In another position

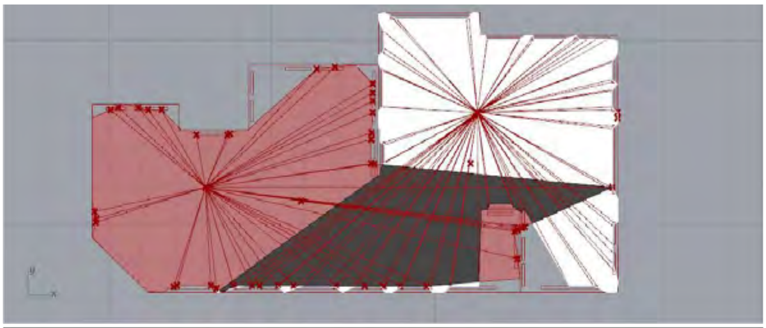

Figure 7. The location of the two different visitors from different locations from decoding spaces component

Designers can deduce the visibility intersection and the hot and cold zones in the exhibition environment. Many other spatial parametric components can be used by designers in the optimization process.

5. Connecting Interactive Evolutionary Optimization and Parametric Design

This paper develops an approach that seeks to explore the different parameters that should be included in the evolutionary process that can enhance the visitor's experience in complex spatial spaces by connecting interactive evolutionary optimization to parametric design in such a way that all the features offered by parametric design in terms of geometry generation can be used to explore innovative structural systems. Consequently, interactive evolutionary optimization must not be limited to a set of structural typologies or design problems. Interactive evolutionary optimization must thus be connected to parametric design in the most lightweight way possible and should only know about the geometry, the performance index, and the design variables of a given problem, allowing the designer to explore any design problem easily and interactively. Connecting evolutionary optimization and parametric design inherently extends the designer's input by not limiting it to the modification of predefined parametric formulations of design problems. Analyzing and visualizing these data in order to gain deeper insights into the effects of spatial variables. These can then be used to support decision making and participatory designing process to analyze the needs of people.
Merging the parameters found in the route of the visitors in order to find solutions to the architectural complexity design.

5.1. Design Optimization

This paper highlights approaches that seeks to connect interactive evolutionary optimization to parametric design which is offered by parametric design in terms of geometry generation can be used to explore innovative design systems.
Using a parametric modelling environment enabling the capture designs, extraction of spatial analytics, and demonstration of how populations can be used to drive the generation and optimization of alternate spatial solutions towards creative exploration, are theoretically applicable to any design problem and are well-suited to make ill-defined criteria meet quantifiable objectives in architectural design.
Building these parametric modeling environments can be used in combination with analysis and optimization components to constitute integrated design environments.
The user and parametric models are optimized Galapagos for Grasshopper for example giving a single near- optimal solution. As a result, parametric modeling as implemented in existing environments lacks of guidance features and design space exploration.

5.2. Fitness Value Selection

The fitness function that evaluates every algorithmic solution from the various generations during optimization process is categorized by the designers themselves according to the design plan and the needs of the different exhibition spaces and behaviors deduced from the observation and simulation by one fitness function or many according to the optimization type.

6. Conclusion

This paper showed the feasibility of the combination of spatial analysis, space configuration and visitor's behaviors with parametric software to come with an optimized result. This provides planners and designers with a powerful tool to analyze their existing project for revitalization or new design to design more functional spaces to meet the needs of the users according to the usercentric approach. These outcomes are used to evaluate their final design which helps the designer produce a more accurate result in line with the purpose of the project.
This paper shows the feasibility of this process through a case study with some parametric analysis components tested and clarifies the existing opportunities and weaknesses as well. The next step is to make the Parametric Design Approach to master layout opportunities to fit more the visitor's needs from accessibility and visibility and clearer for designers to tackle the weaknesses and obstacles in the process.
This approach can enhance the spatial design and maximize views and vistas and identify obstacles which might restrict these. Helps in analyzing the spaces to avoid the creation of "dead space" which is rarely visited by visitors in the exhibition spaces and can become a location of vandalism or negligence. Third the identification of hot spots where visitors visit most can be the best location for some exhibits according to the curator or the designer's plan.

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