Visual Perception of Space and Parametric Design
A Brief Discussion

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Abstract—The use of Parametric modeling techniques in the design process of buildings and built forms produce some characteristic formal expression which many times produce a striking visual interest. This paper outlines how this kind of formal expression influences visual perception. However, this aspect is not considered objectively in the design process. With the help of parametric design, one now has the liberty to explore different design alternatives in less time and with more ease. The paper explores the possibilities of leveraging this technology to parameterize the formal expression of a built space, that thereafter shape up human perception and subsequent decision making - achieving more holistic built-space design approach.

Keywords- Parametric design, Visual perception, Environmental perception, Form, Built Space, Spatial experience.

I. INTRODUCTION

Human beings perceive surrounding environment though various senses. Vision plays a dominant role amongst them. Visual perception involves, firstly, registering necessary information being sourced from various objects whether natural or man-made around the field of vision of human beings and secondly, after initial accumulation of this visual data, the human brain processes them to construct meaningful information (Gibson 1950, Kepes 1965). This information is utilized for various human decision-making and activities including orienting themselves in space (Darken et al. 1998). It also invokes necessary emotions based on visual perception such as sense of well being, pleasantness, distress etc. (Arnheim 1974, Parsons & Daniel 2002). Hence, visual perception of space is of utmost importance to human beings and for that matter the animal kingdom at large as far as their activities, decisions, and emotions are concerned. It could be understood that the visual perception is grossly dependant on the physical objects. In addition, the physical objects whether natural or man-made comprises of various physical parameters. These parameters vary case to case, from time to time. Often these parameters are changed and iterated by the designers to suit to a particular need (Patrick & Kaushik 2013), for example, in case of architecture or built environment. The inclusion of a door fenestration on the approach way or road is preferred since it would indicate a quick entrance to the building visually. Now this door has a height, width, texture etc. which are its physical parameters. A designer may choose to increase the height of the door to make it look pronounced and well defined, and inviting. Or the width of the door is increased to accommodate more people to pass through at the same time with ease in case the building serves to a busy pedestrian influx such as a railway station building. Now, in contrast to a normal residential building, in this case, what have been changed are physical parameters of the door. Nevertheless, the resultant effect is established through visual communication of the same. The visual perception of the door plays a major role in establishing necessary decision making on the users’ part. However, the door is essentially comprised of a set of physical parameters. These parameters create the concept of a door to human beings.

With the advent of computer in the twentieth century, the ease of computation and dealing with complex and multiple mathematical models was vastly facilitated. Multi-parameter driven problem solving became easier. Multitude of disciplines started relying on machine computation, which conventionally was done manually (Mahoney 1988, Naur & Randell 1969). Also simultaneous data handling could be done with very complex numerical data without any error. The concept of providing the inputs to generate reliable output formed a galactic leap in the field of technology affecting almost all traditional disciplines.

Parametric design is a computer aided approach where set of parameters in a relationship, using algorithms form an expression. It helps in bridging the gap between ‘design intent’ and ‘design response’ (Rynne & Gaughran 2007, Schnabel 2007). The relation between various elements in a complex structure or geometry could be manipulated, and its effects could be studied easily, in architecture and urban design it has been used in different ways: from considering energy efficiency to testing structural strength of challenging geometries; from different complex functional relations between spaces to management of construction project with changes in spatial parameters such as height of the building (Jabi 2013, Stavric & Marina 2011). While this tool caters these different varied applications, parametric architecture, in particular, is apparently characterized by their stylistic formal expressions, which have become widely popular. These computer generated forms most of the times provide the user...
new, out-of-the-box spatial experiences. The resulting forms of parametric architecture, which are physical structures, have a unique bearing on its visual perception by the viewer or user. However, not much research has been done to understand this relationship of how or to what extent the visual perception of parametric architecture is affected by the change of the parameters. Is there a way to measure and realize the effects of this type of formal expression of parametric architecture as far as visual perception is concerned. And it has already been discussed that this visual perception impacts human cognition, decision making and emotions. The relationship between visual perception and parametric design is quite fuzzy till date.

A. Aim

This paper aims to show that visual perception of a place or spatial built form could be integrated with parametric design approach. The perceptual attribute through vision is often treated subjectively and is neglected in the domain of core scientific parametric design research. Some advancements have been witnessed in the area of view potential from a building from an economic implication standpoint. However, a deeper causal relationship of visual perception with parametric design holds good potential for research. This paper targets this gap area for its research. This paper is part of a broader research related to evolving a methodology for visual perception of urban places or built environment.

B. Objectives

To fulfill the above-mentioned objective three broad objectives have been set for this paper. These are:

- To analyze through literature study related to parametric design, visual perception and allied cases relevant for the research.
- To building a classification for parameters related to visual perception, this could be subjected to study and experimentation in the realm of parametric design.
- To craft an experiment to envisage on the aim of the research, i.e. to establish that there exists a strong relationship of visual perception of a place or built form and visual perception. And the change in parameters causes a change in perception and thereafter affects the impression of that place. This subsequently affects decision-making and emotions.

This is part of an ongoing research and hence it is a partial understanding of a bigger domain of methodological framework. Where the analysis and design of a place is better affected considering the aspect of visual perception. The paper draws its assumption that there exists a gap in this area and thus suggests a direction of research. The limitation of the research includes demographic, socio-cultural, and econo-academic variations. Different people have different perceptual and impression levels based on their exposure and experiences and hence a thorough research is suggested in a stratified manner for better understanding. This paper utilizes a smaller group for a quick understanding and achievement of the aim of this paper, i.e. to establish there exists a strong relation between parametric design and visual perception.

C. Research Need

The gap in relation to the topic of the paper has already been discussed in the previous section. Hence, there is an academic interest to explore such research domain. Moreover, human decision-making is vastly affected by visual perception, which necessarily draws economic and administrative implications, for example, whether a place looks safe has an implication on investments and authoritative controls of that place. With the help of parametric design, the factor of visual perception along with other parameters could be better integrated into the design process. It would evolve as a part of objective and rational parametric entity and not as an intuitive and qualitative attribute, as conventionally practiced.

The next section of the paper discusses the literature understanding of the topics in discussion such parametric design and visual perception. Thus brings out the key elements relevant for the research, including identification of parameters for visual perception.

II. PARAMETRIC DESIGN

A. Definition

Parametric design can be defined as any set of physical properties whose values determine the characteristics or behavior of something (Lamit 2015). Hence, the design draws its basis from physical parameters that construct the object or space. The change of these parameters results in the change of the characteristics and behavior of the object or space again.

B. History of term

Parametric design in architecture came up in the seventies, with the emergence of methods to describe curves through parametric equations. Steve Coons in 1967 proposed the definition of skewed surfaces by the subdivision in compound patches of four edge curves defined by similar equations for easier operation (Alvarado & Muñoz 2012).

C. Use

Parametric design helps to generate a variety of information about any design - its mass properties, a drawing, or a base model (Lamit 2015). Parametric design is a dynamic, rule-based process controlled by variations and parameters, in which multiple design solutions can be developed in parallel. According to Woodbury (2010), mentioned by Yu, Gero & Gu (2015) it supports the creation, management and organization of complex digital design models. Using parametric design tools, designers can make rules according to the performance requirements of a design (Yu et al. 2014). Hence, in other words, parametric design is helpful in modification of physical parameters affecting design that suits particular requirements or needs based on certain rules set by the designer accordingly.
D. Classification

Since about 1990, parametric design has influenced the development of digital architectural design, in two distinguishable areas, these are:

- Architectural CONCEPTUAL parametric design and
- Architectural CONSTRUCTIVE parametric design.

Concentual Parametric Design

In conceptual parametric design, it is the parameters of a particular design that are declared, not its shape. By assigning different values to the parameters different objects or configurations can be easily created. Here, the formal expression does not have any limitations.

Constructive Parametric Design

Constructive parametric design refers to data embedded within a predetermined 3D object. This parametric concept is realized in various CAD packages like Autodesk Revit, Soft Plan, Nemetschek, ArchiCAD or Chief Architect. Instead of drawing lines, arcs, etc., designers can insert pre-drawn components, doors, windows, load elements, stairs or roofs etc. (Stavric & Marina 2011).

Here the form is affected by the range of pre drawn components present and further limits the designer’s choice on the spatial experience he wants to provide.

Hence, for the scope of this paper, the conceptual parametric design is considered for having greater flexibility and for its dependency on parameters affecting shapes or forms.

E. How parameters are set

Parametric design in architecture can be used in varied ways. For the understanding of creation of parameters, one can look at an example, on how parameters are set, this can be found in the work of Schnabel (2006) where parametric design methodology was introduced in the design studio environment via a workshop. There the students were free to choose two parameters that they would use simultaneously as constraints in their design assignment with the help of parametric modeling software. These parameters informed about the site, and allowed a description of the site based on dependencies and interconnected relationships of site relevant information.

Grouping of parameters by scale: Another paper by Nicolai & Esben (2014), aims at the fast generation of different design scenarios in order to facilitate stakeholder involvement in communicative urban design processes. Some initial results of a test case for the development of an urban design tool have been presented. Working within a sequential hierarchy from terrain to facade, the study has focused on the sequences from site layout over building envelope to facade. This provides an example of how different parameters are grouped together according to their scale.

Grouping of evolutionary design parameters: Researchers have identified four main approaches to handling constraints in evolutionary algorithms:

1) penalty functions that reduce the fitness of invalid solutions, 2) repair functions that modify invalid solutions, 3) specialized reproduction operators that avoid invalid solutions, and 4) specialized genotype to phenotype decoder functions that avoid invalid solutions (Kaushik & Patrick 2013).

III. VISUAL PERCEPTION OF SPACE

Visual Perception is the process of registering visual sensory stimuli as meaningful experience. According to Barry (2002), a perceptual approach to visual communication employs an understanding of the mechanisms underlying the processes of vision and examines how these processes; consciously and unconsciously impose themselves on the formation of attitudes and ideas (Ghosh et al. 2015).

Hermann von Helmholtz (1821 - 94) is often credited with the first study of visual perception in modern times. Helmholtz examined the human eye and concluded that it was, optically, rather poor. The poor-quality information gathered via the eye seemed to him to make vision impossible. He therefore inferred that vision could only be the result of some form of
unconscious inferences: a matter of making assumptions and conclusions from incomplete data, based on previous experiences as cited in the Five Senses by Dr. Pedialopolis (1947).

A. Relation between spatial form and visual perception

Various authors have drawn the visual effects of spaces such as Ching (1979), Rigdon (1974) especially highlights how spatial forms produce psychological effects (Rigdon 1974) -

a. Unbroken space is dramatic, sophisticated, bold, serene, calm, confident, certain, open, simple, straightforward like the little black dress or a Rothko painting

b. Somewhat (not extremely) unequally divided space is intriguing

c. Large broken space is closed-in, busy, complex, and tight

d. Small, broken space is dainty, delicate, feminine, intriguing

Although, parametric design can be used for creating a specific spatial perception, these effects and approach should be taken into consideration as parametric entities rather than as subjective guidelines to the designers, which is the way conventionally visual perception of space is considered in design and subsequent practice (Schumacher 2008).

B. Parameters of visual perception

Since this paper refers to visual perception in context to parametric design. The parametric design and its various aspects have been discussed so far. However to establish a connection, visual perception has to be parameterized in order to adjudge the application of parametric design approach to the same. So far, clear parameterization of various aspects of human visual perception has been treated subjectively and often intuitively. Relying on human intuitive judgments based on common experience and best practices. In order to analyze the perception of users one must consider the different parameters of visual perception objectively and prudently.

This can be achieved by the use of visual communication design parameters. It is a process to communicate a specific message, in predominantly visual form and to obtain a desired response. Like any other form of design, it refers to both the process and the product or the outcome of the process. The surrounding environment is flooded with visual communication design (products) from static graphic posters to audio-visual motion graphics; from signage, maps, info-graphics to digital interfaces – Graphical user interface (GUI). There is immense diversity of media of display and propagation and in terms of stylization. However, there exists certain perceptual unanimity and order – the underlying parameters governing the same.

Cited by Ghosh et al. (2015) (Frascara 2005) has given a categorical growth of visual communication design as a discipline that started differing from artwork and crafts. This transition gave rise to academic research in these areas leading to more objective and analytical understanding of visual communication design. Until beginning of World War I, the conception of visual communication was entrusted to artists or printers. It developed its essential components in 1920s (Art Nouveau, Bauhaus, De Stijl). It changed from artistic creation to effective communication in 1950s, when new developments in psychology, sociology, linguistics, and marketing attracted the attention of designers. This inter-disciplinary and inter-dependent mesh started influencing visual communication design, which in turn conditioned visual perception to a great extent. There emerged standard conventions of visual perception, the parameters started become streamlined and more comprehensive.

Now, it is witnessing the next stage, based on developments in newer technology, which enhances interaction between the public and information. Technology and data that is more instantaneously interactive and more socially knitted gave rise to newer dimensions of visuality and its representation. Also with the rise of consumerism and globalization, it is becoming more versatile and appreciated. People are becoming aware of this easily discernible visual form into almost everything they see. Ghosh et al. (2015) has emphasized how VCD can be used for urban design, and similarly concepts and applications of VCD could be used for more generic aspects of built space or urban environment, which include spaces of varying scales, from urban regional scale to an individual building scale. In this context, section II E, is to be referred to, where it is shown how scale of parameters vary in reference to parametric design.

Hence, we can infer that VCD if applied for such a wide application can be subdivided into following groups (Frascara 2005, Ghosh et al. 2015):

- **Design for Information**: Good VCD system, which is visually appealing, makes a space legible, navigable, and beautiful. This could imply a consideration of the different sightlines of users.

- **Design for Persuasion**: As the terminology suggests, VCD should be persuasive in nature, so that intended behavior or response is achieved from the user. However, it should not be encroaching and overwhelming. This aspect could take care of checking the overall composition the form created throughout user’s route following a given guideline.

- **Design for Administration**: VCD plays a significant role in constituting consistence and unified look, its administration and place branding logistics. Specifications are also governed through visual modes. In addition, if traffic is to be controlled, this aspect could control the visual illusion of diverging or converging spaces.

- **Design for Education**: Every architectural piece and urban place has an identity and a concept to it. The story and identity of the built space could be conveyed via different medium depending on the scale of the built space. A parameter could be considered which would decide the appropriate amount of educational measures (from street level banners/informational kiosks to building level LED screens and posters) that are to be provided in relation to the user’s eye movement path throughout their travel in the space.
IV. INTEGRATING THE TWO ASPECTS/PERSPECTIVES

If the connection between spatial systems and visual perception is analyzed, Ghosh et al. (2015) has established that there exists inter-relationship between VCD and UD, as far as visual perception of urban place is concerned, which directly or indirectly affects urban development and good place making. However, a thorough understanding of the relationship is yet to be established. There is a gap between the visual perception system and the spatial systems (Ghosh et al. 2015). In an approach to solve this gap, quoting Minai (2010) is quoted that would shed some light:

“Atomism, meaning beauty can be referenced to individual objects, or isolated pieces, or segment independent of the context or the whole. Structuralism and contextualism mean that beauty is a matter of the context and does not mean anything in isolated pieces and independent of context. These two correlate with semantics and syntactics …” (Minai 2010)

From the above quote, it can be inferred that the problem at hand is to be studied through its constituent parts. One needs to think of the constituent parameters of each subject: both visual perception and the spatial systems. For e.g., in a building level, architectural scale, if we consider an auditorium, the spatial system can comprise of parameters like the number of rows, seating capacity estimates, riser angles, etc. in relation to visual clarity of the stage or screen of the auditorium (Miller 2009). Similarly, in case of a scale of a group of buildings, it relates to the description of the site based on dependencies and interconnected relationships of the site relevant information (Schnabel 2006) or in case of an urban streetscape, it accrues to the street furniture, illumination, paving, etc. (Ghosh et al. 2015). There has always been an undefined relationship between the formal expression of spaces and their visual perception. The clues from visual perception has always been taken to modify the formal expressions of a building, or built forms in the environment since the use of entasis in Parthenon, to the modifications in form for the aid of visual illusion in Pantheon (Gräßhoff & Berndt 2014),

“Like the thickening of the corner columns, the different contraction factors for columns of different lengths are meant to compensate for optical illusions: For our vision always pursues beauty, and if we do not humor its pleasure by the proportioning of such additions to the modules in order to compensate for what the eye has missed, then a building presents the viewer an ungainly, graceless appearance.”

In later times too, it could be witnessed that Gaudi (1852 - 1926) initially proposed a helicoidally shaped column, like the salomonic columns from the renaissance period. However, Gaudi considered that the single twist was visually inappropriate, since it produced a visual perception of a weak column that could be squashed or deformed. The visual imperfection of the single twist column that bothered Gaudi for a number of years was solved by the use of two rotations. This methodology, which has no known precedents in architecture, is the result of eight years of work and experiments and Gaudi’s interpretation of the helicoidally growth present in trees and plants (Carlos 2005). This type of excessive time consumption for producing design alternatives can now be avoided if we consider visual perception as a part of the parametric design process.

So it could be safely suggested from a historical perspective that visual perception controls the form defining parameters of architecture to some extent, although the exact parametric relation between visual perception and architecture is yet to be derived. This opens up a completely new arena of research in future.

In order to find the exact relations, we can go to little more depth and analyze the visually perceptible elements in terms of shapes and other geometric forms. Weber & Amann (2004) envisage that the existing studies on ‘Shape Grammars’ still don’t establish the connection between cognitive aspects and the design decision-making in the form of rules. The knowledge of these relationships could mean significant progress in the study of the architectural languages (Weber & Amann 2004).

Parametric techniques that already help in design decision making, if considered in relation to such cognitive aspects as discussed above, the results could be of great potential. A small experiment has been crafted through this research to establish this point where the visual perception is integrated in a parametric design nature using shape grammar cognitive features for a built environment.

This gap in existing conventional studies continues to remain since more importance is given to mere formal expressions of built forms rather than its resultant visual perception of the object or the objects together forming the whole place, or rather the image of place, which is perceived by an individual, this is evident from Campbell (2004) words:

"Is it the image or the house that is the end product of the design process? I believe you have to say it’s the image. The house becomes merely a means to the image” (Campbell 2004).

Although an exact relation is unclear and requires further introspection, a theoretical starting point can be made from the subjective implications of formal and spatial effects on visual perception as has been illustrated by Rigdon (1974). Here one comes across the different elements of a designed object and their psychological implications. For example, the six cues that control visual perception of spatial effects have been clearly stated here (Rigdon 1974):

1. Size of spatial divisions
2. Overlapping
3. Closeness of shapes
4. Density of spatial divisions
5. Convectivity and concavity
6. Character of enclosing lines

These aspects are highly helpful while designing intuitively. But if one had to design a highly complex structure within a very limited amount of time where parametric architectural technique would be better suited, then the final form would ordinarily be a product of the functional
Now, for ease of understanding, let us consider only one sub parameter of ‘line’ under the division of ‘Image/ Form’. Figure 4 describes how it further breaks down into smaller components and these components influence the formal expression. In case of a line, the most important factor is its direction as per Rigdon (1974) and to create a sense of balance this directional quality of line can be used to make opposing diagonal lines that convey a sense of balance. However the weightage amongst the various sub-parameters would vary depending the function, usage and scale of the project or design, the relative importance could be assigned as a variable, as per the choice of the designer. Now, for further clarity, let us consider the components as a process.

It could be seen in Figure 5, that first, the parametric model incorporates the parameter line, and then it’s different factors, one of them being direction. Now the different parameters of direction are subdivided into horizontal, vertical and diagonal;
and for further specification, the nature of diagonal line is chosen to be opposing. Next, the most prominent lines in most of the visual frames as a person travels through a space have to be found out (which maybe through scanning eye movement patterns or via brightness discrimination processes). Let us assume that the lines of rafters are the most prominent lines to be found. This guideline of opposing diagonal lines is now implemented on the virtual 3d model of the rafter to create the visual sense of balance.

In this process from the pure physical-visual attribute of a line transcends into more subjective visual attribute of ‘balance’. Thus, the subjectivity and objectivity of visual perception could be dealt together which could now be treated parametrically. Hence, in this way, software can be proposed which can help parametric architecture to put consideration on the visual perception of space. However, more subjective areas like semiotics will need a lot more research to objectively control the different design parameters. Though linguistic semiotics have already delved in rapid progress into computation and parametricity using ontology, and other semantic considerations in computer science and information technology.

V. VISUAL PREFERENCE SURVEY

With an aim of testing the hypothesis relating to the discussion of visual perception and parametric design as an integrated model, an experimental method was adopted.

Visual preference survey was conducted among a sample size of 32 participants. The participants are chosen from a background of architecture or design in order to relate to visual communication more aptly, so that the semiotic congruency could be achieved in the sample under study. They were shown six images of a streetscape. The parameters of the same elements of the streetscape have been changed creating various options. The respondents were to visually analyze the streetscape and were asked to fill up a questionnaire based on their visual preferences regarding the streetscape options. Finally, the results were analyzed quantitatively in order to recon a pattern in the visual response of the participants. This was extremely important, since it shows how much relevant the execution of the theory of integration of visual perception and parametric design would have in a practical setup.

A. IMAGE FOR SURVEY

Figure 6 shows the set of images that was shown to the participants. Among these images, at first a typical version was created, with regular features as shown in E in Figure 6. E was taken as a parent version. This was done based on literature study of landscape design guidelines. Some of the guidelines are mentioned as follows:

- Oval shaped: These plants are suitable for frame or screen.
- Vase shaped: They can be used above the large shrubs or small trees.
- Pyramidal: It can be used as an accent plant.
- Shrubs (edging): To create line effects (as cited in ‘A Handbook of Landscape’, CPWD India, 2013).

Trees should have a minimum height of 1.8 meters when planted to be visually effective (as cited in ‘Landscape Design’, Auckland Council District Plan, 2013).

The other images (A, B, C, D & F) are various child versions of E. They were created by changing the parameters of elements present in E. The modifications done to the parameters are shown in Table 1.

![Image](image-url)

**Figure 6: Image shown to participants**

<table>
<thead>
<tr>
<th>Picture Number</th>
<th>Parameter Changed</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Change of shape</td>
<td>All landscaping colors are limited to one shade of green in order to observe the distinct effect of change of each parameter</td>
</tr>
<tr>
<td>B</td>
<td>Change in distance and continuity of shrubs</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Change in height</td>
<td>Google image</td>
</tr>
<tr>
<td>D</td>
<td>Color variations of E are absent</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Composition according to literature study</td>
<td>Color variations present</td>
</tr>
<tr>
<td>F</td>
<td>Change of shape and color variation observed</td>
<td>Dual influence of shape and color variation is observed</td>
</tr>
</tbody>
</table>

The colors of the streetscape were kept as neutral as possible (other than the trees and sky) so as not to visually distract the viewers. The focus of the study is to observe the effect of change of parameters of physical objects in a build environment, in terms of visual perception of that place and creating some impression. This impression leads to various decision making. Hence, visual perception also has a crucial implication in terms of decision-making factor such as whether the place is walkable or safe. The images were arranged in no particular order in the set in order to keep the observations of the respondents unbiased of any order or sense of continuity.
B. QUESTIONNAIRE

The list of questions asked were as follows-

- Rank the pictures below in the order of "more attractive" to "less attractive" according to you. Write picture numbers as your answer (e.g. C, B, F, E, D, A where C is most attractive and A is least attractive).
- Rank the pictures below in the order of "more organized" to "less organized" according to you. Write picture numbers as your answer (e.g. C, B, F, E, D, A where C is most organized and A is least organized).
- Rank the pictures below in the order of "more walkable" to "less walk-able" according to you. Write picture numbers as your answer (e.g. C, B, F, E, D, A where C is most walkable and A is least walkable).
- Rank the pictures below in the order of "more safe" to "less safe" according to you. Write picture numbers as your answer (e.g. C, B, F, E, D, A where C is most safe and A is least safe).

The framing of these questions were aimed to study the influence of change of parameters of physical characters of the streetscape on the emotional subjective attributes for arriving at a decision, such as, attractiveness, organization, uniqueness, sense of walk-ability and safety. And this process is happening through visual perception. That suffices the aim of this study. All of these participants come from a design or architecture background, and hence they are more accustomed to the attributes mentioned in the questions.

C. ANALYSIS

After conducting the survey, the results were analyzed quantitatively. The data was tabulated in terms of ranks corresponding to the questions. Hence the data was available in form a ranking against each image, compiled for total number of respondents i.e. 32. Hence this calls for a non-parametric statistical approach.

The first test which was applied on the data was to analyze the measure of relationships between columns of ranked data obtained from 32 respondents for each of the image options or conditions. A non-parametric approach for discrete variables is supported by Kendall’s rank correlation coefficient (T) and Kendall’s coefficient of concordance (W), in contrast to Spearman’s rank correlation. Moreover the intent of statistical analysis here is to analyze the degree of agreement or concordance amongst the 32 respondents casting ranks for each of the six images. Hence W has been used, which returns a value ranging from 0 to 1. Where 0 is no concordance between the columns of ranked data, on the other hand 1 indicates complete agreement amongst rankers. In other words, it is a test to signify if the decision of rankers over ranking has been unanimous. Though for this particular experiment, this significance test is of lesser importance as the objective of the experiment is to establish the fact that there exists a parametric relationship between physical characteristics and human impression, and subsequent decision making. It is not an attempt to analyze which features of landscape exactly affects which impressions and to what extent. However this experiment provides a whole array of future research possibilities exploring this facet.

<table>
<thead>
<tr>
<th>Image with highest rank</th>
<th>Image with lowest rank</th>
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<tbody>
<tr>
<td>E</td>
<td>A</td>
</tr>
<tr>
<td>D</td>
<td>B</td>
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<tr>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>E</td>
<td>A</td>
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<td>B</td>
<td>C</td>
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<td>A</td>
<td>E</td>
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Table 2: Kendall’s Coefficient of Concordance (W)

Table 2 manifests the values of Kendall’s W. It could be observed that for all of the conditions, the value of W is significantly high, tending to 1. Except for that of ‘Walk-ability’ where also a tie of two different images has been observed. Hence it is evident that the there is agreement amongst rankers of ranking for the conditions/images. This substantiates the need for parametric approach in visual perception, since this small experiment brings forth the fact that divide in impression and understanding of a place could exist amongst viewers and that should be taken into account statistically, and analyzed as a part of parametric approach. In a bigger context it could exist in much more complex form.

Parametric modifications and subsequent responses which lead to unanimous perception is the key to future design which is more optimum - physically, economically and cognitively. The purpose of this experiment was to probe an essential lead to this area, which required research attention.

Thereafter the ranks for various images obtained from various respondents were compiled for each case, in order to study them cumulatively. Simple method of weighted average has been used where, weight is the value of the rank.

Using, \( R = \frac{\sum(w_i x n_i)}{N} \), where, \( R \) is the weighted average of ranks for a particular image or condition; \( w_i \) is the individual rank; \( n_i \) is the corresponding frequency, i.e. number of respondents assigning that rank to \( w_i \); \( N \) total number of respondents. Table 3 shows the \( R \) value for each of the images across various cases, while its rank interpretation is Table 4.

<table>
<thead>
<tr>
<th>Image with highest rank</th>
<th>Image with lowest rank</th>
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<tbody>
<tr>
<td>E</td>
<td>A</td>
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<td>D</td>
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<td>A</td>
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<td>B</td>
<td>C</td>
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<tr>
<td>A</td>
<td>E</td>
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Table 3: R value showing cumulative ranking

<table>
<thead>
<tr>
<th>Perceptual Impression attribute</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<tbody>
<tr>
<td>Attractiveness</td>
<td>2.97</td>
<td>3.09</td>
<td>3.38</td>
<td>3.91</td>
<td>4.13</td>
<td>3.53</td>
</tr>
<tr>
<td>Organization</td>
<td>4.66</td>
<td>3.84</td>
<td>4.03</td>
<td>2.34</td>
<td>2.47</td>
<td>3.66</td>
</tr>
<tr>
<td>Uniqueness</td>
<td>3.09</td>
<td>4.66</td>
<td>3.72</td>
<td>4.41</td>
<td>3.28</td>
<td>1.84</td>
</tr>
<tr>
<td>Walk-ability</td>
<td>4.00</td>
<td>3.31</td>
<td>4.00</td>
<td>3.59</td>
<td>2.72</td>
<td>3.41</td>
</tr>
<tr>
<td>Safety</td>
<td>4.19</td>
<td>3.03</td>
<td>3.75</td>
<td>3.56</td>
<td>2.78</td>
<td>3.69</td>
</tr>
</tbody>
</table>
### D. RESULTS

After conducting the survey, the results were analyzed quantitatively to determine the ranking pattern. The resulting pattern deduced is shown in Table 5:

<table>
<thead>
<tr>
<th>Perceptual Impression attribute</th>
<th>Ranks of images or conditions based on R value</th>
<th>Image with highest rank</th>
<th>Image with lowest rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attractiveness</td>
<td>6 2 3 5 4</td>
<td>A</td>
<td>E</td>
</tr>
<tr>
<td>Organization</td>
<td>D E F B C A</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>Uniqueness</td>
<td>F A E C D B</td>
<td>B</td>
<td>F</td>
</tr>
<tr>
<td>Walk-ability</td>
<td>E B F D AC</td>
<td>A</td>
<td>AC</td>
</tr>
<tr>
<td>Safety</td>
<td>E B D F C A</td>
<td>E</td>
<td>A</td>
</tr>
</tbody>
</table>

It is evident from the experiment that E is perceived to be the most attractive, walk-able and safe streetscape based on visual perception of the respondents. On the other hand, A is found to be the least attractive, organized, safe, and walk-able. Apart from this, in terms of uniqueness B ranks least while F ranks first. C is also considered to be less walkable based on visual perception.

### E. INFERENCE

From the results it is obvious that the composition (E) as guided by literature study was accepted most positively whereas, deviations from the regular resulted in low ranking in preference. Among these deviations, change of shape has a greater impact on respondents’ decision or impression based on the visual perception of the streetscape. It is the most predominant since A is perceived most negatively in terms of attractiveness, organization, safety, and walk-ability. Other parameters like height and continuity are also important since change in height created the least sense of walk-ability, while the change in continuity and distances between trees created the least uniqueness.

Through these results it could be established that the change in physical parameters of a design, passing through visual perception parameters affected the final impression of that design, in this case it is attractiveness, walkability etc.

Hence, this survey proves there is definitely a relation present between the changes in parameters with the visual perception of a space. And not only that the change of parameters affects the change of perception in an objective way. The reason of which could be analyzed, parametrically varied and tested through modeling. Thus, an optimum solution could be reached based on these parametric iterations and simultaneous checking of the visual perception. However, this is a small experiment to prove the topic under discussion and this is not yet inter-related in a quantified algorithmic manner. However, future experiments in this order and then building up a data repository would create a quantitative model for future research. It is a small step towards rationalizing a highly subjective fuzzy area into a parametric objective domain of design; however, this needs more robust research work for further clarity.

### CONCLUSION

Through this paper, with initial discussion on visual perception and parametric design, thereafter establishing a theoretical-hypothetical inter-connection and then with final experiment proving the relationship, an end to end understanding towards visual perception and parametric design could be narrated.

Thus, on one hand, along with various functional and service attributes, visual perception of architecture, built form and spaces are too parameter based and linked to parametric approach practiced in parametric design.

On the other hand, the outcome of parametric design is subject to visual perception. Hence, the visual perception factors or parameters should be imbued into the very basis of parametric design at its inception.

This paper established the essential clues based on literature reviews and existing research. To test the hypothesis an experiment was conducted and it was analyzed how the different parameter changes in a streetscape design (as an example) would affect the viewer’s visual perception. This gave us an idea of the relation between a definite parameter change and the perceptions caused. This in turn can be seen in the reverse order that would be more useful and relevant for a designer, i.e., a specific type of visual perception requires what kind of change in parameters.

This paper opens up an avenue that can have multifaceted applications due to its generic nature. But for application in any specialized area, first a data base needs to be created through extensive research. This could provide the basis of data for the parametric design software to be used. The software will then use the theory in the reverse direction, with an input of the type of visual perception to be created; it can then utilize the researched data to change relevant parameters and create different design alternatives with desired perceptual results.
For the clarity of visualizing of such a practical potential, in terms of real implementation, the research of Ghosh et al. (2016) could be sited, with the site being at Rajarhat New Town, near the city of Kolkata, India. Figure 7 shows the existing image of a streetscape at Rajarhat New Town. With intense research and further modifications of the model proposed, it is possible to create a software that may analyze and introduce the most visually preferred features and their parameters suitable in the context of New Town and finally propose a solution that may resemble Figure 8. The use of this example is aimed for providing an idea of the huge potential of the hypothesis proposed in this paper. The inferences provide more hope towards a future, quoting Terzidis (1997):

“If one takes the position that designing is not exclusively a human activity and that ideas exist independently of human beings, then it would be possible to design a computer mechanism which relates ideas.”

Further work has been initiated in terms of developing a web-based application which captures users impression on parametric variation in order to design. Where the users visual preferences could be captured ranging over pure parameters. Thus which parameters affect users in which particular way could be analyzed and even averaged out to form a optimized design solution.

Irrespective of the vast possibilities, there is a good potential for future research required for implementation of this theory. This paper hence proposes a direction to the future framework integrating parametric design and visual perception in a holistic manner making the world a better place to live in with its design process being more efficient, effective, optimum, rational and resource saving.

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