Parametricism: Order or Chaos?

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***Abstract* — Parametricism is defined as a groundbreaking discovery in today's digital world. It claims to be the single style for avant-garde architecture, spreading its domains into architecture, planning, and allied design genres such as product design. While parametric architecture looks aesthetically dynamic, it doesn't follow straight-line geometries which are deemed so important by architects such as Le Corbusier. As Corbusier very clearly says in his book The City of Tomorrow, it is the man who follows the straight path, while it is the donkey who meanders; his idea of "order" clearly suggests linear arrangements to the fractal level. Parametricism, on the other hand, lays it down as one of its ground rules that it abstains itself from the usage of linear geometry. It disregards linearity as rigid and considers it its sincere responsibility to break through it. With such strong emotions against Corbusier's idea of "order", how, then, does Parametricism justify order within itself? Or is there no inherent order which is followed by this new style that considers itself the next big movement in architecture after modernism? The route to finding an answer to this question lies in the Theory of Chaos. One of the things that the theory says is that chaos doesn't mean a lack of order; apparent randomness, generated as a result of mathematical expressions with various parameters, only seems random because it has an inherent order which is too complex to be comprehended by the human mind at a single glance. Hence, cases were taken up and studies were done accordingly, leading to the finding that every aspect of parametric design derives its form by virtue of some running parameters, which are fed into computational software, thus generating the form which then falls under the parametric style of architecture; and that no aspect governing the design is arbitrary. Hence, it is proved that parametricism does have a sense of inherent order as is existent in chaos, which, though radically complex and principally contrary to the idea of order that Corbusier had, still holds valid on the grounds of the Theory of Chaos.**

***Keywords* — Architecture, Linearity, Parametric, Theory of Chaos.**

I. Introduction

In his book 'The City of Tomorrow, and its Planning', the first assertion Corbusier makes about urbanism has a reference to the straight line and right angle as means by which man can prove his dominance over nature. In the first two paragraphs, the architect draws a clear contrast between the ways of the man and donkey [1].

According to Corbusier, linearity is the way of the man. Man moves in a well-defined path straight in the direction of his target. He knows extremely well his destination, and hence, devises the shortest way to achieve it. A donkey, on the other hand, wanders about absent-mindedly, stops and meditates numerous times on the way distractedly. It strolls off in zigzag paths in order to avoid big stones, or to make the climb easier, or for a little shade. He prefers to follow the path of minimum resistance [1].

Corbusier's appreciation and admiration for the strict linear order of the Romans are evident in the urban planning schemes proposed by him, such as the gridiron pattern of the planned city Chandigarh. He presses that 'the house, the street, the town … should be ordered; (…) if they are not ordered, they oppose themselves to us' [1]. He strongly opposes any regard for the scenic irregularity of the medieval cities [1].

On the other hand, according to Patrik Schumacher, the father of parametricism, 'the parametricist sensibility gives more credit to the "pack-donkey's path" as a form of recursive material computation than to the simplicity of clear geometries that can be imposed in one sweeping move' [2].

Since parametricism so clearly defies the idea of order in architecture, as defined by Le Corbusier; how, then, with the absence of order can it be considered a rational language for architecture?

II. Research

A. The Notion of Linearity in Architecture

The inherent validity of linearity as a fundamental principle of architectural design has been an established aspect of city planning for centuries [3]. The linear arrangement finds recognition in-laws of geometry as discussed by classical commentators of architecture like Alberti, Lévi-Strauss, Derrida, Shakespeare, Deleuze, Stendhal, and others [4]. A considerable majority of the ancient cities of Greece and Rome are laid out in an orthogonal fashion, with streets adhering to rectangular grids [3]. The temples of Egypt and numerous cities across the globe in India, North Africa, the United States, etc. present strong evidence that orthogonal intersections were considered efficient and advantageous [5], [3]. Corbusier too identifies with the constancy of the idea of linear and rectangular arrangements in city plans throughout history. According to him, the line serves an insurance against whimsicality of an uninformed designer [6].

In his book, 'The City of Tomorrow and its Planning', Le Corbusier talks about the ideal town, elaborating on the principles of town planning. He underlines that geometry is the instinctive language of man and a town is geometry in its purest form. Geometry is the foundational means by virtue of which we are enabled to grasp the world around us; a modernist machine-driven world. The town as a new model of dwelling is derived from the industrial age, therefore

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necessitating that the articulation of architecture is guided by function, thus designing an aesthetic that consisted of pure form [3], [1].

The line is a fundamental and inevitable element of architecture, most essential to understanding the geometry of creation, and the basis of satisfaction. The manifestation of a straight line and a right angle in the plan of a city is a representation of power and will and signifies the epitome of that civilization [6], [1].

B. *Linearity As the Definition of Order*

We struggle against disordered randomness and forever strive to gain order, something which can truly be achieved by appealing to the most elemental thing which our mind can comprehend: geometry. It is when a man begins to draw a straight line that he gains utmost control over himself, propelling him into a state of order [1].

There is a path-donkey's way and a man's way. While man walks along a straight line as he has complete control over himself. He is fully aware of his destination and takes the direct path that leads him straight to it. A donkey on the other hand meanders along the way in order to take the path of least resistance, caused by his inability to keep his instincts under check [1].

Corbusier insists that a modern city is governed by a straight line for every aspect of its existence from buildings to roads, sewers, and highways. The straight line is inevitable. It is the most appropriate thing for designing the heart of a city. The curve, however, is catastrophic, unfeasible, and dangerous. "It is a paralysing thing" [1].

Corbusier's idea of cities was that they should be independent of context, history, or tradition. He was very impatient to the organic nature of the growth of cities over time. As he says in his book, 'a city should be treated by its planner as a blank piece of paper, a clean tablecloth, upon which a single, integrated composition is imposed' [1]. He made sure he inculcated the properties of organization, serenity, forcefulness and order in all his schemes of urban planning [7]. According to him, designs of spaces within a community had the power to reshape society. He also stresses that it is the architect's responsibility to bring about this change. But for this, he needs to be ruthless and unnerved by emotion [7]. He cautions that in ancient Rome, where the organization of spaces had sprouted in a non-orderly and organic fashion, 'the plebes lived in inextricable chaos of abutting (warrens) (...)police activity was extremely difficult' [1].

While reading through his literature, or seeing his architectural drawings, one finds it extremely hard not to notice his unequivocal desire for simple, straight, elegant lines and repetition [7]. He strongly believes that "the human mind loses itself and becomes fatigued by such a labyrinth of possibilities. (…)I eliminate all those things". He also very clearly states that 'I insist on right-angled intersections'. The architect insisted that all building elements must be standardised. All measurements, all ventilation, all lighting, all appliances and equipment, everything must be standardised. All aesthetics should be alike for all latitudes and needs. 'We must find and apply new methods... lending themselves naturally to standardization, industrialization, tailorization.' wrote Corbusier in 1929 [7].

The idea was to segregate all functions and limit them to the areas designated to them in the urban plan. This was done because it was believed by Corbusier that it is remarkably easier for an urban planner to shape a zone if it is dedicated to only one purpose and only a particular set of facilities. When the variables multiplied themselves, it proved to be a serious challenge for the urban planner, such as the case when several purposes need to be accommodated in a single zone. Corbusier liked to be in command of all variables. He calculated the amount of heat, light, air, and space required by humans and concluded that it was 14 square meters per person, which could be reduced to 10 if the activities being performed within the space were communal in nature [7].

The principles proposed by Le Corbusier had a massive influence on the system of urban planning during the modernist era, in spite of being thoroughly radical, highly strict, and totalitarian as far as symmetry, order, and standardization were concerned. These principles slowly and steadily found themselves leading to the development of several typologies for new high-density housing throughout the world [7].

The Radiant City was another concept proposed by the architect, falling completely in line with his modernist idea of progress by virtue of complete disregard and the annihilation of tradition. This new city was to arise over a tabula rasa, the blank grounds created by the destruction of the ancient and vernacular European cities. It would boast the presence of numerous prefabricated, high-density skyscrapers. These towers would be scattered over a large area and would be organised in none other than a strict Cartesian grid. This, he says, would enable the functioning of the city as that of a 'living machine'. He earnestly explains that 'the city of today is a dying thing because its planning is not in the proportion of geometrical one-fourth. The result of a true geometrical layout is repetition; the result of repetition is a standard; the perfect form' [8].

C. *Parametricism-A New Perspective on Architecture*

According to Patrik Schumacher, parametricism is where every property of all the elements can be computationally associated- made cause and effect- with any other property of any other element in the design. The designer takes intelligent decisions as to the formulation of correlation and rules of this governance. These correlations are similar to those omnipresent in nature. Thus, every element is designed so as to potentially network and resonate with every other element in the network [9].

The programming of the variables of morphological output can be done in such a way that they respond to the parameters of the environmental input. For instance, there exists a data set that maps the sun exposure, which can be used to create a map for the exposure of façades to radiation intensities during different time periods. This map can be used as a data input for the adaptive modulation of a system designed for sun-shading. The system of shading elements drapes the façade, each element of this system dynamically altering its physical properties so as to achieve the desired values of sun exposure at their specific locations on the façade. The resultant obtained is a gradient, continuously transforming façade pattern, which offers the correct optimization for the levels of sun protection relative to the light intake at every point of the façade of every element in the sequence [9].

This form of dynamic logic applied to each individual element also adds to the aesthetic quality of the entire system as a whole. It also makes the orientation of the building more comprehensible, in addition to better navigation legibility of the urban environment. The articulation of the façade in such a differentiated manner helps the façade transmit significant amounts of information about the position of the built, rather than continuing to remain contextually indifferent and blind [9].

Schumacher described how 'recently we witnessed an accelerated, cumulative build-up of virtuosity, resolution, and refinement, facilitated by the attendant development of parametric design tools and scripts that allow the precise formulation and execution of intricate correlations between elements and subsystems.' [2].

Today, there are continuous advancements in computational design processes with new and superior technologies coming up each day. These play as big a role in the growth and propaganda of parametricism as parametric designers' sense of realization of the extremely unique organizational opportunities presented by these processes. Parametricism can exist and flourish only by the exceptional enhancement in the sophisticated levels of appropriation of computational geometries. Computationally advanced tools of design for scriptings like Mel-script or Rhino-script, and for parametric modeling with tools such as GC or DP are becoming an extensive reality [2].

According to Schumacher, the following 5 agendas are to introduce new features into the parametric model, and to boost parametricism further [2]:

1) Parametric inter-articulation of sub-systems: The aim is to progress from single system differentiation, for instance, a swarm of façade components, to the programmed organization of multiple disjointed subsystems– structure, envelope, voids, internal subdivisions, navigation, and so on. The differentiation in any one system is associated with differentiations in the other multiple systems.
2) Parametric accentuation: The objective is to enrich the overall sense of organic integration of various elements through correlations that support deviation amplification or intensification rather than adaptations suggested as compensation. The associated system should emphasize the initial differentiation. Thus a far more powerful enunciation can be achieved, and more familiarizing visual information can be communicated.
3) Parametric figuration: It is observed that parametric variations trigger "gestalt-catastrophes", i.e. the quantitative alteration of these parameters lead to qualitative shifts in the perceived configuration. Hence, in addition to object parameters, ambient parameters and observer parameters also need to be incorporated into the parametric system.
4) Parametric responsiveness: Urban and architectural environments have an inherent dynamic capacity that permits those environments to reorganize and alter themselves in response to prevalent occupation patterns. The real-time registration of the patterns of usage of each environment guides the real time kinetic adaptation. The built environment thus attains responsive intervention at various time scales.
5) Parametric urbanism-deep relationality: The systematic variation of morphologies produces powerful urban effects and assists orientation on field. The aim is to integrate the building morphology- right to the detailed spacial articulation and the system of interior arrangement.

D. The Apparent Lack of Order in Parametricism

The ground rule of parametricism is malleability. It lays it down as one of its foundational principles that no element is rigid and everything has the ability to be parametrically modified. Parametricism claims that in contrast to all the previously existent styles of architecture which focus on assembling hermetic and rigid geometric figures, it introduces multiple elements having the inherent characteristic property of adaptability to changes [9].

These changes could be of any nature, ranging from the climatic response, contextual variation, or mutual coordination. The key to the generation of designing using such ways is variation and correlation [9].

According to Patrik Schumacher, the man who is considered to be the father of parametricism, the following lie in the root of this new and emerging style of architecture [9]:

1) Negative heuristics (taboos)

1) Rigid geometric primitives like squares, triangles and circles need to be avoided
2) simple repetition of elements has to be abandoned
3) the juxtaposition of unrelated elements or systems has to be prohibited

2) Positive heuristics (dogmas)

1) all forms are to be considered as parametrically malleable
2) differentiation has to take place gradually and at variant rates
3) systematic inflection and correlation need to happen

E. The Mathematical Meaning of Order and Chaos

In 1960, an American meteorologist, Edward N. Lorenz sat in a laboratory of the Massachusetts Institute of Technology, trying to model the weather. He had created a weather model comprising twelve equations that associated factors such as temperature, wind speed, and pressure. His computer computed weather reports for periods specified by him at regular intervals. A review of these printouts generated by the computer showed that his model was following the weather patterns of the earth. Pressures and temperatures rose and fell, winds changed directions and air currents swayed north and south. One day the meteorologist decided to repeat a set of calculations already completed by him previously. In order to save time, he decided to rerun the calculations from the midpoint of the previous simulation. He read the previous values from the printout and entered the approximate values into the computer. The results generated, as checked by him an hour later, completely took him by surprise! [10]

The results of the second simulation were drastically different from those generated during the last run, all because of the approximation of a certain inputted value. To the biggest amazement of the meteorologist, after the simulation for a few months, any kind of resemblance between the two runs had completely vanished. But how was that possible? The results of both the calculations should have been more-or-less the same considering that the same program was being used. The answer lay in the values. Instead of 0.506127, he had entered 0.506, and the thousandth part had in turn made all the difference. The result was the formulation of the theory of chaos, stating the extreme sensitivity to initial conditions. Today, we would probably be right in saying that Lorenz had discovered a chaos [10].

The Theory of Chaos is applicable to systems that are dependent on the input of an initial value based on which the system proceeds to form a complex network of data. The theory is called the 'theory of "chaos"' since it states that no matter how random the results or the outcomes of the processed data may seem, they are highly dependent on the initial conditions i.e. the initially inputted values. The apparent 'randomness' in the outcome is because of the minutest discrepancies in the initial conditions. These slight variations in the initial input can lead to a series of feedback loops, repetitions, fractals, and self-organization which can lead to results that could be strikingly non-similar. Fascinatingly, this process gives rise to a complex system, which is based on non-random and completely logical functions such as loops and repetitions [11].

Even for systems that are deterministic in nature, i.e. whose future behaviour depends solely on the initial conditions and have no random elements involved at any stage of the processing; even minute differences in the initial input values such as rounding-off errors, etc., can lead to astonishingly diverse outcomes [12], [13].

III. Discussion

A. Parametricism: The Parameter-Driven Design Process

No matter how random and disordered the designs emerging on parametricism may seem, it is observed that all of them derive their physical characteristics such as form, location, orientation, heights, etc. from a set of very well-defined parameters, which are very-well thought-out after thorough considerations of many factors.

These are factors such as the physical, cultural, and social aspects of the context. Unlike Corbusier's ideology, context is deemed highly significant in the parametric way of thought, as can be seen in both case studies. The topography of the site is also a highly sensitive factor. The arrangement of the buildings in the immediate surroundings of the site is also a deterministic factor since it leads to the determination of the access points into and around the site.

The sun path and the sun angle are major regulatory factors for deciding the façade geometry and the system of fenestrations and openings. Light and heat are dependent on these parameters.

In larger urban design projects such as the Kartal-Pendik Masterplan, much importance is given to the major building typologies and how they merge to form an integrated urban morphology. The system of roads and circulation is also a parameter to resolve the grid. The heights of various elements in the cityscape are other major governors. Plazas and other public spaces in the whole scheme are also paid attention to.

Deformation no longer denotes the breakdown of order but the lawful impression of information. Orientation in a complex, lawfully differentiated field affords navigation along vectors of the transformation [2].

The location and enunciation of building entrances might be associated with the differentiated navigation system of the urban morphology. This correlation might even range to internal circulation. This concept of profound rationality might also function in reverse so that, for instance, something like the internal organisation of a major institutional building might lead to a set of multiple entrances that in turn bring about the need for adaptations within the overall urban navigation system [2].

The forms owing to all these parameters combined are generated and controlled through computer-based design software. These softwares not only assist in the design process but also play a major role in the execution of these complex schemes. For instance, the façade panels on each façade of each tower of the Kartal-Pendik Masterplan need to be designed individually owing to such an immense variation in the geometries of each panel due to the magnified differentiation of parameters. And each of these panels needs to join with the ones in its surroundings to create a smooth, seamless exterior surface. This computation cannot be possible without the use of these highly intelligent computational softwares.

No physical entity in parametricism is free from parameters. Every physical quantity follows logic in its design. If not so, it has to follow the logic required for its execution since every bit of execution is computer-based.

B. From the Lens of The Theory of Chaos

To further study the behavior of systems which are sensitive to initial conditions, Lorenz decided to simplify his system by developing a three-equation, or a three-variable system that did not model the weather but modeled convection, a part of the atmosphere. In his 1963 paper, the meteorologist listed the output of his calculations: (0,10,0); (4,12,0); (9,20,0); (16,32,2); (30,66,7); (54,115,24); (93,192,74). Lorenz obtained hundreds of these triplets. What he wanted to do was to find out how these variables changed with time [10].

The technique he used to analyze his data was by graphing it. Lorenz used each set of three numbers to represent a point in a three-dimensional space. The result of this plot would be a series of points. Connecting these points generates a continuous path which is a register of the behavior of the system [10].

The resulting pattern looked like an owl's face or a butterfly's wings. The path follows a harmonic motion, going back and forth between the "wings", however never repeats itself. The behavior signaled disorder since no path ever recurred. At the same time, the behavior signaled order since all the paths were confined in the overall pattern [10].

Since each set of initial conditions was observed to result in a different path within the overall pattern, Lorenz concluded, "Prediction of the sufficiently distant future is impossible by any method, unless the present conditions are known exactly. In view of the inevitable inaccuracy and incompleteness of weather observations, precise very-long-range forecasting would seem to be non-existent." What the meteorologist is saying is that because of the complexity of the atmosphere, we can never have enough information to be able to have accurate weather forecasts [10].

Science also uses the terms chaos and disorder, accompanied by the term non-random. In science, their degree of predictability marks the difference between all these terms. A process is non-random or ordered when it allows predictability in both theory and practice. When one has to weigh the success of a scientific method, successful predictability is an important determiner. For instance, the law of gravitation can be applied to predict eclipses of a thousand years into the future or the past [10].

A process is random when it is completely unpredictable. When what has happened in the past cannot be used in any way to predict the possibilities in the future. An example is raindrops hitting a surface. The falling of one raindrop does not give any suggestion about when or where the next raindrop is going to fall [10].

A chaotic process is one that falls in between these two extremes of total predictability and total unpredictability. Because equations can be written to describe the behavior of chaotic systems, they are in theory predictable. Yet, in practice, they are only temporarily predictable and eventually become unpredictable. [10] This happens due to the various running processes such as series of feedback loops, repetitions, fractals, and self-organization, etc. [11].

C. Apparent Randomness Does Not Imply Lack of Order

The terms geometric ‘order’ and ‘chaos’ are used very casually for architectural compositions even though the definitions for these concepts is very difficult and complex. It can roughly be said that ideal mathematical forms such as square, triangle, circle etc. represent order while forms and relationships which are complex and difficult to describe with the language of classical mathematics are said to represent chaos [14].

From the lens of spatial perception, other definitions may be considered. Fig. 14 shows two graphic compositions, each consisting of about 1600 points. The average density of points is uniform in the entire area of both compositions. In the first composition, a small circular area of regular points is noticeable on the background of randomly arranged points. In the other composition, it is the inverse, i.e. a small circular area of random points is visible on the background of regularly arranged points [14].

Chaos looks erratic. However, it is not merely a vast sea of disorder. Behind apparent randomness are some interesting features. For example, continued increase in the value of a control parameter in the logistic equation doesn't necessarily bring about increased degrees of chaos in the system. However, each systematic increase in the control parameter, no matter how slight, does bring about an altered trajectory each time. (And hence, even within chaos, the parameter is king!)

However, in the domain of chaos, such an increase often leads to some type of regularity, something like order. All of those regularities are quite traceable and reproducible, for a given value of the control parameter. Curiously, the order usually lasts for only over brief ranges of the entire control parameter. At the very least, chaos can be seen to consist of various types of order camouflaged under random-like behavior. In that sense, order within chaos is the rule rather than the exception [15].

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Conflict of Interest

Authors declare that they do not have any conflict of interest.

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