FROM NUMBERS TO DIGITS:
ON THE CHANGING ROLE OF MATHEMATICS IN ARCHITECTURE

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

FROM NUMBERS TO DIGITS: ON THE CHANGING ROLE OF MATHEMATICS IN ARCHITECTURE

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This study is a critical reconsideration of architecture's affiliation with mathematics and geometry both as practical instrument and theoretical reference. The thesis claims that mathematics and its methodological structure provided architects with an ultimate foundation and a strong reference outside architecture itself ever since the initial formations of architectural discourse. However, the definitive assumptions and epistemological consequences of this grounding in mathematical clarity, methodological certainty and instrumental precision gain a new insight with the introduction of digital technologies. Since digital technologies offer a new formation for this affiliation either with their claim of a better geometric representation or mathematical controllability of physical reality (space), the specific focus on these newly emerging technologies will be developed within a theoretical frame presenting the significant points of mathematics in architecture.

Keywords: mathematics, geometry, science, number theory, architectural theory, digital architecture.

ÖZ

SAYILARDAN BASAMAKLARA: MATEMATİĞİN MİMARİDE DEĞİŞEN ROLÜ ÜZERİNE

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Bu çalışma mimarlığın, matematik ve geometri ile pratik bir araç ve teorik bir referans olarak kurduğu ilişki üzerine eleştirel bir incelemedir. Matematik ve matematiğin metodolojik yapısının mimarlık söyleminin ilk oluşum dönemlerinden itibaren nihai bir temel ve güçlü bir referans olduğu iddia edilmektedir. Fakat, bu nihai temel ve bu temelin epistemolojik çıkarımlarının dayanağı olarak kabul edillen matematiksel açıklık, metodolojik kesinlik, ve araçsal duyarlılık, sayısal(digital) teknolojilerin mimarlık pratiği içerisine girmesiyle yeni bir boyut kazanmıştır. Bu teknolojilerin kullanımının fiziksel gerçekliğin ya da uzamın geometrik temsili ve matematiksel kontrolüne dair önermiş olduğu yeni oluşumlar, mimarlığın matematik disiplini ile olan ilişkisi içerisindeki dönüşüm noktalarının kuramsal çercevesi özelinde tartışılacaktır.

Anahtar Kelimeler: matematik, geometri, bilim, sayı teorisi, mimarlık teorisi, sayısal mimarlık.

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I am also indebted to my family for their encouragement and support; and I owe a particular dept to my father for his thought stimulating critics and suggestions. The discussions that we have made and the quarrels that we have had either on philosophy or on architecture are the most essential references of my life and in specific this particular research.

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CHAPTER 1

INTRODUCTION

Starting from the late twentieth century, the intrusion of digital technologies to the contemporary field of architectural practice brought forth many discussions either related with their use as drafting tools or as form-generative media. The present interest with the digital medium resulted in various questions and developed equally various approaches in architecture concerning the implication and value of these technological tools in the design process. Although the significance of the practical precision and numeric control of the design process that these digital media provide are accepted without any dispute, the theoretical underpinnings of this affiliation still occupy a crucial part of contemporary architectural criticism.

Whereas that kind of a broad criticism requires taking into consideration different fields, this study limits its investigation to the changing theoretical claims of architecture's practical use of mathematics.[1] As practical advantages of this affiliation are mainly formulated around the gains that mathematics and mathematical relations provide throughout the architectural process the aim of this study is to critically reconsider the asserted achievements of architecture's utilization of this mathematical precision in practice both as a controlling

[1] In its broad sense, digital technologies are accepted to include also the widening utilization of information technologies. Under the concept of virtuality or virtual reality, and within the discussions of the blurring status of presence, a good many of studies mainly focus on the social, political, ethical, cultural, economical and aesthetic consequences of the change in digital era, through the extended use of communication networks and information storage technologies. See; Paul Virilio, *the Aesthetic of Disappearance*, *Speed and Politics* or *The Lost Dimension*; or William Mitchel, *City of Bits: Space, Place, and the Infobahn*; or Neil Leach, *The Anaesthetics of Architecture*, etc., However, since the aim of the study is not to focus on the changing comprehension of architecture and architectural process under the influence or domination of network systems, some aspects of the digital period are excluded yet their impact is not neglected.

mechanism and as a guiding agent. And more significant than to manifest the outreaches of this exploitation, the study intends to develop a critical framework in order to discuss the theoretical consequences of this affiliation.[2] Asserting that the relationship which the so-called digital era has reestablished with mathematics is not a new nor a recent one, architecture's previous engagements with number and geometry are re-examined regarding the consequences of this affiliation. In that respect, the goal of the study is not just to examine the present condition, that is architecture's use of mathematical relations ensured by the digital technologies within a closed system that the ongoing researches provide, but to develop a critical framework through the reflections of previous commitments. As regards, the first chapter will firstly investigate on the initial formation of mathematical concepts and continue with a brief survey of significant turning points in mathematics with respect to their reflections in architecture.

Prior to the 19th century developments in mathematics and the rise of the positivistic attitude, the use of number and geometric relations in building practice were accepted to be the reflections of a higher mathematical order and unity that the nature possesses.[3] Numbers' uncertain relation with the existing things was not overcome till Plato's theory of *Ideas* with which the philosophical explanation of physical reality gains an explicit form and status.[4] As regards, the two antique philosophical traditions, i.e. the Platonic and the Aristotelian are outlined within the framework of the first chapter with respect to their distinctive approach to

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[2] In the course of this theoretical layout the thesis adopts the epistemological framework developed by Zeynep Mennan in her Phd. Thesis. Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd. Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997. Mennan states that the discipline of architecture is in need of grounding in its search for an objective ground. In this sense mathematics is taken as a grounding platform for architecture.

[3] Ernst Cassirer. *The Philosophy of Symbolic Forms, Volume 1: Language,* Virginia: Yale University Press, 1965, p. 73.

[4] Ibid., p. 73.

mathematics and mathematics' relation to physical reality. The significance of the Platonic tradition for the acceptance of mathematical concepts as abstract entities is examined with respect to Plato's general theory of *Ideas.* The privileged status of abstract mathematical concepts over deceitful observations of sense experience in Platonic thought is given with respect to its counter arguments developed by the Aristotelian tradition. Plato's sharp distinction of "the world of İdeas" and "the world of things"[5] and his acceptance of mathematical relations as the unchanging, absolute truths of the physical world[6] is compared with Aristotle's "theory of matter" that denies any kind of reasoning which transcends the boundaries of the given world.[7]

The Euclidean construction of space is taken for granted as the unification of these two counter traditions, as in Euclid's "*Thirteen Books,"* geometry is established as a closed and complete system, the concepts and relations of which are accepted to correlate well with physical space.[8] Euclid's mathematical implications were mainly the outcome of a methodical simplification and abstraction of observed phenomena.[9] The translation of observed qualities of space into systematic relation of geometric quantities is accepted to become the

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[5] Luc Brisson. "Plato's Natural Philosophy and Metaphysics," in *A Companion to Ancient Philosophy,* (edited by: Marry Louise Gill and Pierre Pellegrin) Oxford: Blackwell Publishing, 2006, p. 218.

[6] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, New York: Oxford University Press, 1972, p.44.

[7] R. J. Hankinson. *Cause and Explanation in Ancient Greek Thought,* Oxford: Oxford University Press, 2001, p. 126.

[8] Hans Reichenbach. *The Philosophy of Space and Time*, Trans: Maria Reichenbach and John Freund, New York: Dover Publications, 1958, p. 1.

[9] Morris Kline. *Mathematics in Western Culture*, New York: Oxford University Press, 1959, p. 43.

major contribution of the Greek period not only to mathematics but also to the fields that function in space such as architecture.[10]

Although architecture's use of mathematical entities and equations is accepted to date back to Babylonian or Egyptian settings by some mathematicians,[11] in this study the historical outline of architecture's relation with mathematics is surveyed starting with the Greeks since a theoretical background was first given by them.[12] Though the practical significance of geometric proportions in Greek architecture lies in the possibility of offering a "mathematical layout" and a "methodological system" that is useful in practical investments,[13] in its symbolic utilization, the "theory of proportion" is seen to provide for "ultimate harmony" and "absolute beauty."[14] Therefore the rules of mathematics turn out to be the major source of architectural production and the application of these rules are taken for granted as either confirmation or appraisal of an order that is beyond the boundaries/domain of pure (practical) knowledge provided by mathematics.[15]

The genuine appraisal of mathematics as a practical instrument in architecture came about with the Renaissance architectural production through the application

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[10] Hans Reichenbach. *The Philosophy of Space and Time*, p. 1.

[11] Morris Kline. *Mathematical Thought from Ancient to Modern Times*, pp: 3-25.

[12] Vitruvius's theory of proportion in his "*Ten Books on Architecture*" is taken for granted as the initial attempt in theorization of architecture's relation with mathematics. Richard Padovan. "The Harmony of the World Made Manifest in Form and Number," in Richard Padovan. *Proportion: Science, Philosophy, Architecture,* London and New York: Spon Press, 2003. pp: 1-17.

[13] P. H. Scholfield. *The Theory of Proportion in Architecture,* Cambridge: Cambridge University Press, 1958, p. 17.

[14] Vitruvius. *The Ten Books on Architecture*, Trans: Morris Hicky Morgan, Illustrations: Herbert Langford Warren, New York: Dover Publications, 1960, p. 175.

[15] Françoise Choay. *The Rule and the Model: On the theory of Architecture and Urbanism,* Ed. Denise Bratton. Cambridge and Mass: The MIT Press, 1997, p. 2, 20.

of perspectival methodology as a mode of representation. However, as noted by Alberto Perez Gomez, though the general explanation of physical phenomena was geometrical in Renaissance thought, the method of its revelation was not more than an "absolute image" provided by the technique of perspective.[16] The unity in all perceptual, physical and phenomenal change is accepted to be an expression of the divine intelligence that rules the cosmos through a mathematical structure.[17] The structure of macrocosm and microcosm is claimed to be reducible to numbers and ideal geometric structures, and their working principles are regarded to be describable in mathematical terms.[18] The clarity that mathematical description provides in the explanation of physical phenomena is also accepted to correlate well with the needs of the mind in search of clear/lucid ideas and concepts.[19] The precision of mathematical inferences and their transparency to the human mind confirmed the superiority of logical methodology (i.e. deduction) and the authority of reasoning over what was considered as deceitful inferences of observation/perception.[20]

The acceptance of perception as a source of knowledge did not come to terms until 17th century developments in natural philosophy.[21] The science of matter became the essential study field of the period stating that the whole physical order

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[16] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science,* Cambridge, MA: The MIT Press, 1983, p. 89.

[17] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 172.

[18] Morris Kline. *Mathematics: A Cultural Approach*, London: Addison-Wesley Publishing Company, 1962. p. 15.

[19] Bertrand Russell. *History of Western Philosophy,* London and New York: Routledge, 2007, p.43.

[20] Martin Jay. *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought*, California: University of California Press, 1994, p. 81.

[21] Ibid., p. 84.

could be reducible to *matter* and *motion* and were completely explicable in terms of these two concepts.[22] Correspondingly, matter was accepted to be the sole reality of physical phenomena governed by mathematical laws. In that regard, the idea of nature became an independent entity, the very fact of which is supposed to be graspable only through experience.[23] Under the influence of the 17th century's rising scientific methodology, the new source of architecture was claimed to be nature that is written in mathematical terms.[24] This new method of investigation manifested by the mathematical and scientific works of the seventeenth century, not only favored the role of "reason" in revealing the order of the universe but also cleansed the metaphysical and theological presuppositions of the classical period.[25] Though architecture's involvement with this new methodology did not last more than two decades, 19th century developments in mathematics and the intrusion of new mathematical concepts that are independent from the physical necessities initiated a new practice for the use of mathematics in the field of architecture.

Nineteenth century advances in theories of other possible geometries, namely the non-Euclidean, devastated the ground that mathematics had established with the world of things and with the physical space to which these things belong.[26] The consequence of these developments was a break off in the symbolic/

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[22] Morris Kline. *Mathematics: A cultural Approach*, p. 445.

[23] Morris Kline. *Mathematics in Western Culture,* p. 246.

[24] Hanno Walter Kruft. "The Foundation of the French Academy of Architecture and the subsequent challenge to it" and "Relativist Architectural Aesthetics, The Enlightenment and Revolutionary Architecture" *A History of Architectural Theory From Vitruvius to Present.* Trans. Ronald Taylor, Elsie Callander and Antony Wood. New York: Princeton Architectural Press, 1994, pp: 128-165.

[25] Morris Kline. *Mathematics in Western Culture.* p. 243.

[26] Hans Reichenbach. *The Philosophy of Space and Time*, p.4.

transcendental meaning of mathematics as the essence of all physical reality and the governing principle of all phenomena.[27] Accordingly it is claimed by the nineteenth century mathematicians/philosophers that mathematics is not the correlate of the ultimate truth of lived space, and in extension it is not the answer to the essential questions of meaning and *being*.[28] Thereafter, it is maintained that there is no one truth on physical reality, but multiple answers to the one question on physical phenomena, the validity of which is assumed to be a conventional agreement.[29] Though it is hard to state that the modern period took full advantage of mathematical developments of the nineteenth century[30], the envisaged attention can be said to have come about with the intrusion of digital technologies.

Digital technologies' (or in specific terms CAD (Computer Aided Design) tools) incursion of the architectural process gave way to deliberate studies regarding architecture's relation with technological instruments. The mathematical certainty, clarity and exactness that have come up with the intrusion of digital technologies are not only regarded as the most essential achievements of the architectural process on the way to a more transparent, quantitative practice, but also acknowledged as the raising/changing paradigms of this involvement.[31] Correspondingly, architecture's relation with mathematics and mathematical relations take a new route highly distinct from its prior engagements.

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[27] Ibid., p. 6.

[28] Ibid., p. 6.

[29] Elie Zahar. *Poincaré's Philosophy: From Conventionalism to Phenomenology,* Chicago: Open Court Publishing Company, 2001, p.70.

[30] P. H. Scholfield. *The Theory of Proportion in Architecture,* pp: 75-96.

[31] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*, London and New York: Spon Press, 2003, pp: 13-28.

As regards, the extended possibilities of visualization, the surmounted limitations of construction and representation achieved through digital technologies are seen to require a new understanding of design practice distinct from any previous assessment.[32] Therefore architecture's utilization of digital tools is claimed to be a revolutionary stage for the architectural process, starting from the architect's conceptualization of the initial idea to the production of the architectural edifice.[33]

Accordingly, the influence of the developments in information and communication technology or the effects of the advances in computer science, enforcing diverse experimental studies, become the most challenging implements of most disciplines as well as architecture. Easy storage, documentation, categorization and manipulation of data put diverse disciplines on the same realm while making any specific information of each available to all.[34] As regards, the resolution of specialized information that belongs to different disciplines opened the way for architecture to an interdisciplinary approach.[35]

This interdisciplinary context erasing any boundary line of the architectural discipline itself formed a new exchange platform in which concepts, metaphors, or images from a wide range of fields such as mathematics, physics, molecular biology, topology, fractals, chaos theory, DNA sequencing became the main references.[36] Disparate formal, programmatic and structural elements taken from

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[32] Ibid., p.13.

[33] Ibid., pp: 13-54.

[34] Alicia Imperiale. *New Flatness: Surface Tension in Digital Architecture,* Berlin: Birkhäuser, 2000, p.38, 79.

[35] Ibid., p.38.

[36] Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd. Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997. Also; Antoine Picon. "Architecture, Science, Technology, and the Virtual Realm,"

these fields or disciplines are started to be re-integrated within what Alicia Imperiale names the "neutral space of digital technologies"[37] through techniques provided by digital technologies."[38] As regards, the numeric control lies behind the creation, the development or realization of any architectural product in the digital process is seen to force not only the formal vocabulary of an architectural heritage but also any acknowledged principle or norm in the conception of design process.[39]

Accordingly, in the course of this so called revolutionary process, the authority of compositional principles is devaluated on behalf of the extended possibilities of "morpho-ecologies", "habitat-site systems", "genetic algorithms" and "evolutionary structures" [40] which can be generally termed as self organizing material systems. The mathematical models that lie behind the creation of complex biological morphologies are started to be applied to the architectural process to achieve unpredictable and emergent results.[41] A morphogenetic approach to architectural design that entails "unfolding morphological complexity

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Architecture and the Sciences: Exchanging Metaphors, Antoine Picon and Alessandre Ponte (eds.), Princeton: Princeton Architectural Press, 2003, p. 292.

[37] Alicia Imperiale. *New Flatness: Surface Tension in Digital Architecture,* p. 38,79. Imperiale defines these techniques specifically as "visual layering" or "morphing" tactics, strategies or methodologies.

[38] Jeffrey Kipnis. "Towards a New Architecture," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 19.

[39] Zeynep Mennan. "Des Formes Non Standard: Un 'Gestalt Switch'," *Architectures Non Standard*, Ed. Fréderic Migayrou and Zeynep Mennan. Paris: Editions du Centre Pompidou, 2003. pp. 34-41.

[40] Helen Castle (ed.). Techniques and Technologies in Morphogenetic Design, *Architectural* Design, Vol. 74 No. 3, 2004.

[41] Michael Weinstock. "Self-Organization and the Structural Dynamics of Plants," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 27.

and performative capacity from material constituents"[42] is assumed to take the place of traditional architectural methodologies that necessitate a direct causality between the initial idea and the final form.[43] Accordingly, the architectural form, rather than being the "projected idea of the architect", [44] is started to be considered to emerge through interaction of self organizing components. Since the formation of an architectural edifice in these digitally driven self-organizing processes is seen to be a direct outcome of the internal interactions, the process of architectural production has become to be conceived as a controlled experiment.

In that regard, Brian Massumi notes, developments in digital technologies providing explorative and experimental investigations are accepted to cause a shift in the conception of the architect's role in architectural production, while displacing its classical definitions.[45] Accordingly, developments in digital technologies, being more than a practical utility, started to threaten the once celebrated role of human reasoning which was assumed to be the sole connection between the architectural object and the architect's ideation.[46] In that regard, the architect's intentionality in architectural production is put into question on behalf of the extended possibilities of a digitally driven formal process. Therefore, the well-regarded independency of form from the personality of the architect is supposed to lead to a "neutral business of architecture" that emanates out of the

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[42] Achim Menges. "Polymorphism," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 79.

[43] Achim Menges. "Instrumental Geometry," in *AD: Techniques and Technologies in Morphogenetic Design,* p. 43.

[44] Ibid., p. 27.

[45] Brian Massumi. "Sensing the Virtual, Building the Insensible," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 198.

[46] Fredric Jameson. "Aronoff and Ideology," in Peter Eisenman. *Blurred Zones: Investigations of the Interstitial*, New York: The Monacelli Press, 2003, p. 62.

underlying data derived from an external source.[47] Destabilizing the pure authority of the author/architect on the object, the production of architectural form is then claimed to be determined by data derived from external sources or fields.[48]

The utilization of external source information through a mathematical layout in contemporary architecture is claimed to find its visualization in generative diagrams of formal production.[49] However, unlike any previous visualization technique utilized in architecture, diagrams are mostly regarded as lined networks of relationships that are completely "vague in *formal expression*".[50] Diagrams in that regard, are accepted as visualization devices that integrate different functions and information through interaction and relation of forms under the control and guidance of mathematical relations.[51] Accordingly, the contemporary exploration of mathematical layout in diagrammatic architecture is seen to offer a new possibility for architects to manipulate, modify and transform any idea without sticking to determinate conceptions, ideations or idealizations of traditional methodologies of either representation or formal/typological production.[52]

Concerning the outlined historical background, this study investigates on the shifting role of mathematics in architectural production. In that regard, nineteenth

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[47] Ben van Berkel and Caroline Bos. *Techniques: Network Spin*, Amsterdam: UN Studio and Goose Press, 1999, p. 165.

[48] Bernard Cache. "Topological Architecture and the Ambiguous Sign," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 128-129.

[49] Ben van Berkel and Caroline Bos. *Technique: Network Spin*, p. 19.

[50] Lars Spuybroek. *Nox: Machining Architecture,* New York: Thames and Hudson, 2004, p. 2.

[51] Peter Eisenman. "Diagrams of Interiority," in Peter Eisenman. *Diagram Diaries,* New York: Universe Publishing, 1999, p. 52.

[52] Peter Eisenman. "Diagram an Original Scene of Writing," in Peter Eisenman. *Diagram Diaries,* New York: Universe Publishing, 1999, p. 27.

century developments in mathematics and the emergence of non-Euclidean geometries are considered as a turning point for architecture with respect to the rising disciplinary conventions/agreements on the instrumental comprehension of mathematics. The study then critically reconsiders contemporary architecture's recent relationship with these nineteenth century developments in mathematics asserting that the present use of mathematical relations and numeric control mark an instumentalization procedure as they started to be conceived as just tools for a transparent, productive and generative formal process.

In that regard, although the study historically surveys some significant turning points, it does not aim at making a new contribution or alteration on the accepted comprehensions of neither the history of mathematics nor that of architecture. In that respect, the thesis does not have any historiographic claim. In belief of the importance of the history of ideas, this study is an attempt to survey the changes in the comprehension of mathematics and their profound effect in the architectural profession.

Therefore, the selection of the periods and the choice of central figures are due to the focus of investigation in terms of the relative emphasis given to change and continuity in theories of mathematics. In that regard, the survey made through this study is largely an interpretative history of mathematics apprehended in the field of architecture with a specific focus on contemporary developments in digital technologies. It is therefore a review of how mathematics became significant in the conceptual and practical achievements of architects and architectural critics. Accordingly, what is primarily intended within the scope of this thesis is to make an archeology of some noteworthy moments when a historical change prevails either by pioneers or by shifts in systems of thought.

CHAPTER 2

FROM THE TRANSCENDENTAL TO THE INSTRUMENTAL USE OF NUMBER

The creation of the architectural object has always been at the center of the discussions related with architectural theory.[53] As noted by Mark Gelernter, these questions, in general, locate themselves in a line with two opposing stances on both ends: (1) the architectural object as a reflection of creative imagination and (2) the architectural object as a reaction to a specific function or a particular condition.[54] This dual conception of the genesis of the architectural object, Gelernter asserts, can be read as an indication of two broader approaches in architectural theory that are "creating (art) and knowing (science)."[55] Whereas theories of creation reclaim the superiority of the ingenuity of the architect and his/her creation, theories of knowledge are seen to make the emphasis on the determinant role of external source information.[56]

Though the foundation of most historical theories on the creation of the architectural object can be identified with disparate stances that focus on either art or science, their reflection in practice brings forth hybrid approaches or the interaction of both. As regards, although the questions mainly stress on the problems of creating, it can be asserted that the underlying intention is

[53] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science,* Cambridge, MA: The MIT Press, 1983, p.7.

[54] Mark Gelernter. *Sources of Architectural Form: A Critical History of Western Design Theory,* Manchester and New York: Manchester University Press, 1995, p. 3.

[55] Ibid., p. 28.

[56] Ibid., p. 29-34.

concentrated on developing a reasonable theory of architectural production which will serve as a guiding principle for the architectural practice and in specific, the creation of form. In that respect, most studies on the general framework of architectural theory have always been in close relation with theories that belong to the field of art on the one side and science on the other.[57] Although contemporary approaches to architectural theory from an artistic or scientific point of view mainly depend on the author's position, till nineteenth century the difference between science and art has not been quite a valid question. [58]

For the historical representatives of architectural theory, such as Vitruvius, Alberti, Perrault or Blondel, even if the question is related with architectural/formal creation, the approach to the subject matter has always been

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[57] The debate about architecture's location on the line between arts and science is the one the roots of which could be traceable since the antique period. It seems that for a discipline like architecture, the problem starts with the question of whether the "clarity, unity, and aesthetics" of an architectural object is due to the pleasing of the eye or of the mind. A somehow parallel debate can also be traced between Aristotelian and Platonic tradition in their treatment of nature. While Plato in belief of a mathematically governed universe accepted the seize of eye as deceitful, and privileged the mind's grasp of an underlying mathematical order; Aristotle, highly critical about this comprehention, argued on the reduction of natural phenomena to an abstract systems, whose qualitative principles are totally disregarded in the quantitative structure of such abstract fields (as mathematics and geometry). Actually, although this contradiction belongs to a more complicated and elaborate systems of thought, such a basic implication seems to be crucial: whether it is the eyes of the body or the eye of the mind which is the main determinant of the deductions on nature? Whether it is theory or observation that holds the central point on the conclusions? This never ending discussion on the achievement of knowledge in philosophy has also correlates both in architectural theory and in architectural practice, which will be discussed throughout this study focusing on how these contesting approaches affected the theory of architecture and its consequential reflections in practice. In that respect the books; Asher Benjamin. *The Rudiments of Architecture: Being a Treatise on Practical Geometry, Grecian and Roman Mouldings, the Origin of Building, and the Five orders of Architecture,* New York: Da Capo Press, 1972 (first edition published in Boston in 1814); John Ruskin. *The seven lamps of architecture 1819-1900,* London: J.M. Dent & sons, ltd.,1969, are some of the examples that consider architecture as art. James S. Ackerman. *Distance Points: Essays in Theory and Renaissance Art and Architecture,* and Erwin Panofsky. *Perspective as Symbolic Form,* are the other authors who believe that architecture though affected from artistic investments, has an autonomous status.

[58] James S. Ackerman. "Ars Sine Scientia Nihil Est": Gothic theory of Architecture at the Cathedral of Milan". *Distance Points: Essays in Theory and Renaissance Art and Architecture,* Cambridge, MA: The MIT press, 1991, p.211-263.

terminated within scientific frames.[59] In that respect theory's inevitable self-location in between two fields/poles of knowledge, that is art and science, can be explained with architecture's never ending questionings on the concepts of form, beauty, (in general being) and their relationship with function, goodness (in general doing).[60] In order to exceed the polarity between the realm of beings and the act of doing, and to provide for a meaningful model of unification, theory is accepted to be a necessity.[61]

The reason for architectural theories' search for such a rational, unifying ground is mainly related with the ascribed meaning to architectural practice.[62] In other words, it can be asserted that the need for an overarching explanation of practice was a consequence of the belief that the act of practicing which belongs to the physical or phenomenal realm is open to become a part of subjective choice and preference. A theoretical ground therefore was seen to be a necessity for the practicing architect in order to set the principles of his/her work, and direct his process without any individual explanation related to the particular work alone.[63] Since, historically it was believed that the meaning of architecture is beyond the act of building and constructing, or that it is more than a response to the functional needs, theory was seen to be the mediator or the fulfilling agent between realized architectures and the idea of the architect.[64]

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[59] Peter Galison. "Buildings and the Subject of Science," in *The Architecture of Science,* Ed. Peter Galison and Emily Thompson. Cambridge and Massachusetts: The MIT Press, 1999, pp: 1-25.

[60] David Smith Capon. *Architectural Theory Volume Two: Le Corbusier's Legacy,* New York: John Wiley & Sons, 1999, p. 4.

[61] Hanno Walter Kruft. *A History of Architectural Theory from Vitruvius to Present,* p. 16.

[62] Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd. Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997.

[63] Hanno Walter Kruft. *A History of Architectural Theory from Vitruvius to Present*, p. 16.

[64] Ibid., pp: 14-16.

The reason for that kind of an inquiry on the foundations of architectural practice and architectural ideation essentially takes its roots from the belief that the visible realm of architecture, has to be a result of or at least has to be directed by the invisible, normative rules or principles, which will transcend the subjective, historically situated, temporal aspects of architectural practice.[65] This kind of a will in architectural theory's formation of itself however, is mainly a consequence of the desire for an objective, a-historical, normative ground that will provide a reasonable explanation of architect's intention.[66] Since the architectural practice by its nature does not provide architects with more than generalizations, architectural theories' demand for normative, universal, objective principles has always been shaped through its affiliation with disciplines other than itself.[67] As the basic necessity is formed around a rational, universal, objective ground, mathematics and geometry are seen to have been the most essential references both for architectural theories and for architectural practice.

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[65] Diana Agrest. "Introduction: Practice vs. Project," in Stan Allen. *Practice: Architecture, Technique and Representation*, London: Routledge, 2000, p. xiv.

[66] Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd. Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997.

[67] Ibid., p, 40.

2.1) Abstract Deductive Reasoning and the Birth of the Mathematical Spirit

2.1.1) From a Practical Tool to a System of Thought

As stated by Morris Kline, mathematics' initial formation was a result of man's general quest for certainty, and his awareness that a variety of objects share some common properties that are detachable from these objects and applicable to the others.[68] Cassirer notes that the first attempts on defining the common properties of objects were characterized primarily around existing things, and that the general formations had mainly focused on the real substances.[69] Some physical substances such as earth, air, fire and water, because of their qualitative properties were accepted to be the underlying essences of all physical phenomena.[70] Since, the focus is mainly on visible properties of objects, for a long time the emergence of abstract mathematical concepts were postponed.[71]

Although some practical geometric equations were in use especially in calculation of some causes of the natural phenomena, and in application of some geometric regulations to the building site, the necessity of an abstract system that inherently involve predictive results were never ended either in natural philosophy or in architecture. Because architects and astronomers were dealing with appearances/images or ideas that are not realized materially or with objects that are too far to make one to one measurement, mathematics and geometry for them

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[68] Morris Kline. *Mathematics: A Cultural Approach*, p. 29

[69] Ernst Cassirer. *The Philosophy of Symbolic Forms, Volume 1: Language,* Virginia: Yale University Press, 1965, p. 73.

[70] Ibid., p. 73.

[71] Ibid., p. 73.

were the only methods that enabled to make exact applications and precise predictions about their subject matter.[72] The exactitude that comes up with its methodology made mathematics the only true means to transform architects' and scientists' ideas and objectives to material reality. Thereupon, mathematics, since ancient times, has been utilized for the creation of architectural object and for its application to the construction site or used to predict the working mechanism of the cosmos. Mathematical and geometric rules were used in building practice to measure the areas, to calculate the volumes, and to determine the boundaries which serve for quantification and hence easy management of the architectural process.[73]

It was with the employment and the emphasis of the ancients to the power of human reason that the nature of mathematics took a new route on its development.[74] As claimed by Morris Kline, as a result of the emphasis on the power of human reason in Greek thought, so many investigations started to took place on the nature of physical objects which would not go beyond than derivations of common experiences, unless mathematical methodology is introduced as a mode of reasoning.[75] The focus on the methodology of reasoning then resulted in a new apprehension of nature which is an extension of human mind.[76] The basic motive that lies behind the rationalization process of natural phenomena is the belief that the nature is created through mathematical principles and ordered within mathematical relations that the initiators of mathematics had

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[72] Robin Evans. "Architectural Projection" in *Architecture and Its Image,* Montreal: Canadian Centre for Architecture, 1989, p.19.

[73] Morris Kline. *Mathematics: A Cultural Approach*, pp: 11-14.

[74] Ibid., p.16

[75] Ibid., p.16

[76] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, New York: Oxford University Press, 1972, p. 172.

believed.[77] Therefore, mathematics is considered to be a mediator between mathematically ordered physical reality and its perception/realization/-apprehension by man.[78]

2.1.2) Reasoning and the Strength of Mathematical Construction

The emergence of mathematical reasoning in Greek thought is a result of the realization that common experience is too complex for accurate description.[79] In that regard, mathematics was accepted to provide for the proper abstraction. Since mathematics enables to accomplish a purely intellectual study of nature, investigation on natural order is not restricted with the limits of sense experience.[80] Under the ancient Greek mathematical approach to physical reality lies the belief/affirmation that "nature was rationally and indeed mathematically designed, and that man's reason chiefly through the aid of mathematics, would fathom that design."[81] Such reasoning about general, abstract concepts was accepted to provide for not only hundreds of physical situation in one proof, but also had the capacity of producing the kind of predictive knowledge which experience might never suggest.[82] The production of further knowledge about the subject, its distinction from the sense experience which is believed to be susceptible to external forces, and its formation around abstract concepts are

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[77] Ibid., p. 172.

[78] Ibid., pp: 172-173.

[79] E. T. Bell. *The Development of Mathematics*, New York: McGraw Hill Book Company, 1945, p.8.

[80] Morris Kline. *Mathematics: A Cultural Approach*, p.16

[81] Ibid., p. 16

[82] Ibid., p. 15

assumed to be some of the properties that figure the power of mathematical reasoning. E. T. Bell states on the power of mathematical reasoning as follows;

> This abstracting of common experience is one of the principal sources of the utility of mathematics and the secret of its scientific power…By abstracting and simplifying the evidence of senses, mathematics brings the worlds of senses and daily life into focus without myopic comprehension, and makes possible a rational description of our experiences which accords remarkably well with observation.[83]

The second aspect that makes mathematical reasoning powerful is its methodology: deduction. Deductive reasoning starts with certain statements called *premises*, and any achieved results are made within the frame of the first set of the premises, or at least inescapable from them.[84] The advantage of yielding an indubitable conclusion is taken for granted as the main motive of preference for one that uses mathematical reasoning.[85] Wesley Salmon defines the explanatory power of the deductive method that the mathematics depends on under four headings: He asserts that "they have a universal form (1), within their unlimited scope (2) and they do not contain designation of particular objects (3). Since they contain only purely qualitative predicates, any reference to particulars is excluded (4)."[86]

2.1.3) An Acquired Universality

The properties of deductive reasoning that form the basic methodology of mathematics, like many other members of other disciplines has been the specific interest of architects. In order to undertake a purely intellectual study of their

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[83] E. T. Bell. *The Development of Mathematics*, p. 9.

[84] Morris Kline. *Mathematics: A Cultural Approach*, p. 39.

[85] Ibid., p. 39.

[86] Wesley Salmon. *Scientific Explanation*, (Philip Kitcher and Wesley Salmon eds.) Minneapolis: University of Minnesota Press, 1989, p.13-15.

subject, they accepted mathematics and in specific “geometry as an instrument not to represent things to themselves, but to reason upon them.”[87] The consequence of this intellectual apprehension and in particular mathematical methodology is claimed to have an “acquired universality.”

In that respect it seems important for the aim of this study to explore on the foremost initiators of this ideal in the Platonic and Pythagorean traditions. Therefore the following chapter will focus on the assumed mathematical layout of the cosmic order, and the role and value of abstract mathematical ideas over sense experience. As regards, the subsequent subchapter is a survey of Platonic and Pythagorean traditions on one side and the opposing Aristotelian tradition on the other side.

[87] William Ewald. *A Source Book in the Foundations of Mathematics: From Kant to Hilbert,* Oxford: Clarendon Press, 1999, p.1010

2.2) Mathematics and the Cosmic Order

2.2.1) Mathematics as the Order and the Essence of Natural Phenomena

Beyond the Greeks' acceptance of the mathematical concepts and relations as practical tools, lies their belief in the mathematical order of nature. Mathematics for Greeks was "part and parcel of the investigation on nature and a key for the comprehension of the universe, as mathematical principles are the essence of its design."[88] Bertrand Russell states that the major Greek contribution to the very concept of mathematics was the conscious recognition of the fact that mathematical entities and relations are abstractions and ideas entertained by the mind that are sharply distinguished from physical objects or from their observation by sense experience.[89] In that respect mathematics being an ideal construct of the mind was seen to comprehend with the reality of nature.[90]

Therefore, mathematical relations and geometric explanations became the key sources of astronomy and cosmology which were the main study fields of natural philosophy. It was believed by the Greeks that everything that forms the cosmos was "the offspring of flux and movement."[91] The cosmos divided into two regions, i.e. microcosm (terrestrial sphere) and macrocosm (celestial sphere) was seen to be in a perpetual state of change and motion.[92] Though the first attempts

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[88] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 145.

[89] Bertrand Russell. *History of Western Philosophy,* p. 43.

[90] Ernan McMullin. "Conceptions of Science in the Scientific Revolution" in David C. Lindberg. And Robert S. Westman (eds.) *Reappraisal of the Scientific Revolution*, Cambridge: Cambridge University Press, p. 29.

[91] R. J. Hankinson. *Cause and Explanation in Ancient Greek Thought,* Oxford: Oxford University Press, 2001, p. 7.

[92] Bertrand Russell. *History of Western Philosophy,* p. 151.

on the explanation of change in natural phenomena was made through *prima materials,* i.e. earth, water, fire and air[93] in Greek thought, the search for an immaterial, abstract guiding entity or principle was never to end.[94] Studies on mathematics and geometry henceforth became the main challenges of Greek thought for the explanation of the working principles of the cosmos.

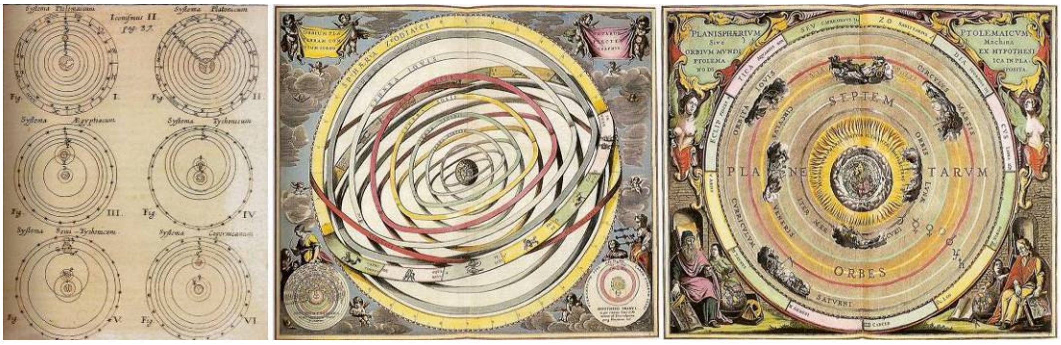

Figure 1.1: Depiction of the superlunaryworld consisted of several circles and spheres. **Source:** Alexander Roob. *The Hermetic Museum: Alchemy & Mysticism.* Köln: Taschen, 2006, pp. 49-51. Originally in; A. Cellarius. *Harmonia Macrocosmica,* Amsterdam, 1660.

In that regard, trying to explain the celestial and terrestrial motion with perfect spherical geometries, the Greeks were accepted to set the way for the mathematical explanation of the cosmos. The observational data of motion and change for Greeks was an ephemeral property which should be replaced with unchanging mathematical rules. Because mathematics has the power of explaining various changes in one proof, it was accepted to be one of the higher wisdoms to understand the functioning of the universe. The possibility of applying the same

[93] R.J Hankinson. *Cause and Explanation in Ancient Greek Thought,* p. 9.

[94] Morris Kline. *Mathematics: A Cultural Approach*, p. 15.

abstract rules and equations to hundreds of different physical situations became mathematics' major contribution to speculative knowledge.[95]

The recognition that mathematics deals with abstractions may with some confidence be attributed to the Pythagoreans.[96] Although it is hard to claim that Pythagorean theory could achieve the required distinction between the existing/material things and the mathematical concepts, Pythagoras's search on the ultimate origin of physical reality in numbers was a significant contribution to the emergence of mathematical concepts.[97]

The reason in Pythagoras's insistence on the mathematical demonstrability of natural phenomena was the belief that the diversity in phenomena exhibits identical mathematical properties from a qualitative point of view.[98] Therefore it was accepted that the mathematical properties are the essences of all phenomena.[99] Numbers and numeric relations were seen to be the first and utmost principles of nature.[100] For the Pythagoreans, all objects were made up of "points or units of existence" from which the geometrical figures are produced. [101] Since

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[95] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 171.

[96] Walter Burkert. *Lore and Science in Ancient Pythagoreanism*, Trans. Edwin L. Minar. Cambridge and Massachusetts: Harvard University Press, 1972, p. 36.

[97] Charles H. Kahn. *Pythagoras and the Pythagoreans,* Cambridge: Hackett Publishing Company, 2001, p. 28.

[98] Bertrand Russell. *History of Western Philosophy,* p. 43.

[99] Antony Gottlieb. *The Dream of Reason: A History of Philosophy from the Greeks to the Renaissance,* New York: W. W. Norton & Company, 2002, p. 30.

[100] Charles H. Kahn. *Pythagoras and the Pythagorean,* p. 26.

[101] Eduard Zeller. *Outlines of the History of Greek Philosophy*, Revised by: Wilhelm Nestle, Trans: L.R. Palmer. New York: Dover Publications, 1983, p. 72. The Pythagoreans regarded these units of existence as the beginning of all things from which the Dyad (the two or the other) is produced and then from it the numbers, from numbers the points, from points the lines, from lines

they conceived of the numbers both as points and as elementary particles of matter, for the Pythagoreans "numbers were the matter and form of the universe" and "the cause of every phenomenon."[102]

Figure 1.2: Engravings that depict Pythagorean studies on the mathematical and geometric harmony of the universe and the first attempts on the way to construct mathematical concepts as independent, abstract entities. **Source:** Robert Lawlor. *Sacred Geometry: Philosophy and Practice*. London: Thames & Hudson, 2002, p. 7.

The exact departure of the mathematical concepts from physical things however came about with Plato's theory of *Ideas* (*Eidos*).[103] In the form of a clear image,

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the surfaces, and from the surfaces the solids. All creation in that regard was believed to be mathematical in origin.

[102] Walter Burkert. *Lore and Science in Ancient Pythagoreanism*, p. 43.

[103] Plato. "Parmenides" in *Plato: Complete Works,* John M. Cooper and D. S. Hutchinson (Eds.). Trans. Mary Louise Gill and Paul Ryan. Cambridge: Hackett Publishing Company, 1997, 130, -a,b,c,d,e.

the “Idea” for Plato is the a priori existence of concepts in the mind.[104] Mathematics and geometry being the most abstract systems of thought, had therefore a privileged status in the Platonic theory of *Ideas*.[105]

However for the Platonic theory, the mathematical ideas were parts of a more general problem: The harmony of the universe. In belief of a mathematically structured universe, Plato defined harmony as the mutual interpretation of “one and many,” or “unity and plurality” not only in *the realm of Ideas* but also in *the objects of experience*.[106] As the concept of “Being” is identified with One in connotation with the terms identity, unity and constancy, the notion of “beings” that belong to the realm of experience was defined as a derivation from the One and associated with contrast, change and multiplicity.[107]

In that respect as it is observed by Walter Burkert, the concept of One not only implies singularity but also includes the Ideal, the Good, the Supreme, and the cause and explanation of every change and diversity.[108] The concept of oneness in Platonic thought, ideal, immaterial and abstract, was the ground of a mathematical structure that rules the cosmos through numbers and geometric forms.[109]

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[104] Ibid., 130,-a,b,c,d,e.

[105] Bertrand Russell. *History of Western Philosophy,* p. 143.

[106] Walter Burkert. *Lore and Science in Ancient Pythagoreanism*, p. 85.

[107] Ibid., p. 21.

[108] Ibid., p. 22. Plato’s reduction of the multiplicity of the world to the four elements, the elements to regular solids, and these to triangular surfaces, can best exemplify the search for a unified whole which can be explained under the concept of One (p.17).

[109] Plato. “Timaeus” in *Plato: Complete Works,* John M. Cooper and D. S. Hutchinson (Eds.). Trans. Donald J. Zeyl, Cambridge: Hackett Publishing Company, 1997, 53,-b.

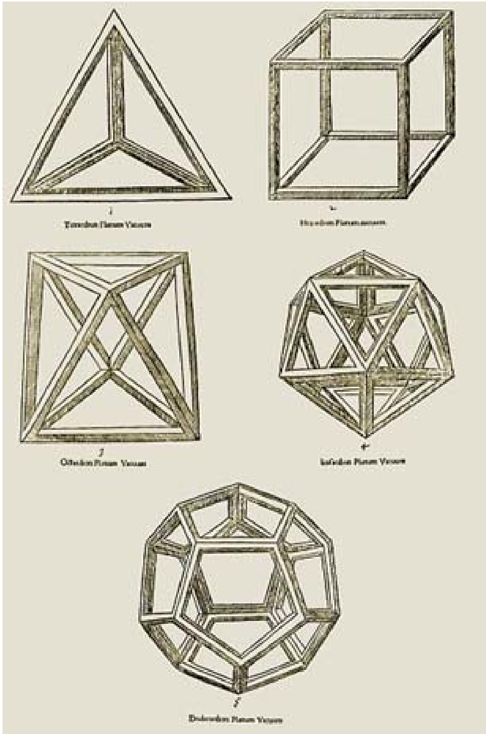

Figure 1.3: Platonic solids. In his dialog *Timaeus* Plato defines geometric shapes as the essence and common ground of all existing things. Triangle being the primary geometric entity is claimed to be the basic shape from which first the other geometries such as cube, isosceles or tetrahedron is constructed and later the cosmos is created. **Reference:** Plato. "Timaeus" in *Plato: Complete Works.* John M. Cooper and D. S. Hutchinson (Eds.). Trans. Donald J. Zeyl, Cambridge: Hackett Publishing Company, 1997, 53,-b+.

However, unlike the Pythagorean theory of numbers, for Plato numbers and geometrical concepts have nothing to do with the material existence of the things that they represent.[110] They have a reality of their own, independent of the experience.[111] In that regard, for the Platonists, there is a sharp distinction between "the world of Ideas" and "the world of things."[112] Because the material

[110] Plato. "Republic VI" in *Plato: Complete Works,* John M. Cooper and D. S. Hutchinson (Eds.). Trans. G.M.A. Grube, rev. C.D.C. Reeve. Cambridge: Hackett Publishing Company, 1997, 510,-d.

[111] Morris Kline. *Mathematical Thought from Ancient to Modern,* p.43.

[112] Luc Brisson. "Plato's Natural Philosophy and Metaphysics," in *A Companion to Ancient Philosophy,* (edited by: Marry Louise Gill and Pierre Pellegrin) Oxford: Blackwell Publishing,

world is subject to change and the relations perceived in it by sense organs are deceitful, mathematics and mathematical relations with their ideal unchanging character should be the absolute truth of the physical world as grasped by the mind.[113]

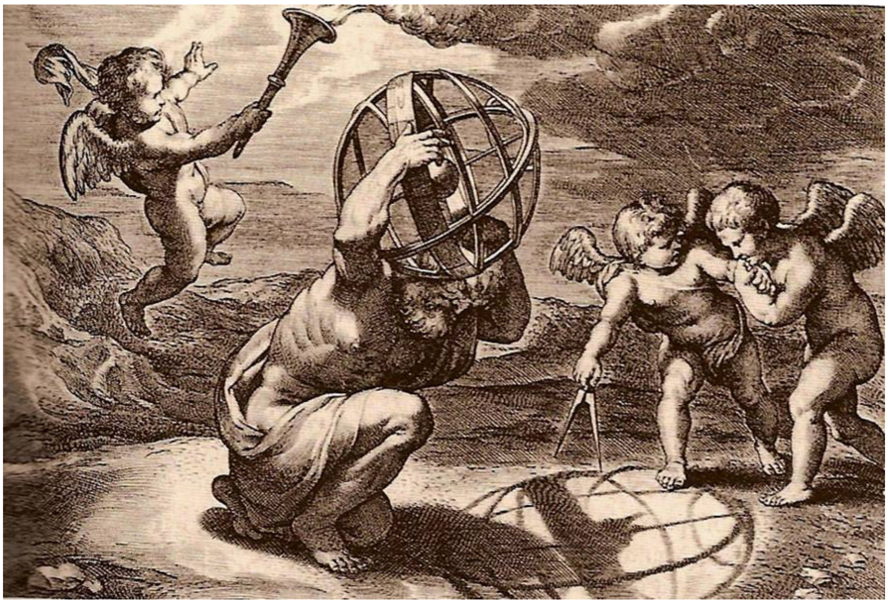

Figure 1.4: The geometric world order. **Source:** Alexander Roob. *The Hermetic Museum: Alchemy & Mysticism.* Köln: Taschen, 2006, p. 55. Originally in: Franciscus Aguilonius, *Optica*, 1611.

For Plato, the physical world is an imperfect realization of the ideal world and as a consequence it is subject to decay.[114] Therefore for the Platonic thought, sense

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2006, p. 218. The theory of ideas in Platonic thought brings forth a double conception of the world: on the one hand "the world of intelligible forms, immutable and universal realities that are the object of true knowledge and discourse" and on the other hand "the world of sensible realities, which participate in the forms, of which they are mere copies."

[113] Morris Kline. *Mathematical Thought from Ancient to Modern Times*, p.44.

[114] Plato. "Republic VII" in *Plato: Complete Works,* John M. Cooper and D. S. Hutchinson (Eds.). Trans. G.M.A. Grube, rev. C.D.C. Reeve. Cambridge: Hackett Publishing Company, 1997, 517-518.

experience and in specific observation cannot be the proper way to study the physical world.[115] The reliable accurate knowledge can only be obtained by means of pure, ideal, intelligible forms which find its designation in mathematics and mathematical relations.[116] Observation, he believed, can only provide *opinions* about the physical world, whereas a perfect *theory/knowledge* of physical reality has to be a consequence of reasoning.[117] Mathematics and the methodology of reasoning with respect to their permanent, universal, accurate and incorruptible character are the only acceptable ways in achieving the reality of the physical world and the principles of its functioning.[118] Plato appreciated mathematics not as an abstraction from nature but rather as a substitution for nature.[119]

Aristotle while deriving many ideas from his teacher Plato, had a quite different conception of the real world and the relation of mathematics to physical reality. He criticized Plato's "otherworldliness" and "his reduction of science to mathematics."[120] As regards, unlike from the Platonic conception of the physical reality, Aristotelian physics is based on sense-perception, and is therefore decidedly non-mathematical.[121] "Plato's world of eternal and unchanging Forms, imperfectly represented in matter by a divine Artisan," was charged by Aristotle

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[115] Ibid., 517-518.

[116] Plato. "Republic VI" in *Plato: Complete Works,* 510-511.

[117] Bertrand Russell. *History of Western Philosophy,* London and New York: Routledge, 2007, p. 123.

[118] Morris Kline. *Mathematical Thought From Ancient to Modern Times*. New York: Oxford University Press, 1972, p.44.

[119] Ibid., p.151.

[120] Ibid., pp:151-152.

[121] David Bostock. *Space, Time, Matter and Form: Essays on Aristotle's Physics.* Oxford: Clarendon Press, 2006, p. 23.

and replaced with a *theory of matter* that has inertly the will for self control and the search to realize its own nature.[122] The Aristotelian theory of matter which is goal-oriented in terms of self-realization rejected the need for an external imposition, guiding or ruling system or structure, either geometric or mathematical.[123] Therefore for Aristotle, the reality of the physical world which consists of "prime matter" cannot be totally treated within the abstract realm of mathematics and numeric relations. For Aristotle, as mathematical concepts and relations are abstractions from the real world, they have no independent reality apart from the visible and tangible things.[124] Since qualitative differences cannot be reducible to different mathematical entities, for Aristotle mathematics alone can never provide an adequate definition of substance.[125] Mathematics is accepted to provide only a description of the changes in physical phenomena.[126] It can give a description of the formal causes but it can never give the accurate explanation of the initial causes of physical changes and movements.[127]

Asserting that the timeless realm of figures and numbers are devoid of quality and motion, Aristotle refused to substitute mathematical abstractions for the dynamic, qualitatively determined facts of common experience.[128] Proposing to remain within the limits of *common-sense reasoning* which derives its concepts from observation, Aristotle devaluated any kind of reasoning that transcends the

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[122] R. J. Hankinson. *Cause and Explanation in Ancient Greek Thought,* p. 125.

[123] Ibid., p. 126.

[124] Morris Kline. *Mathematical Thought from Ancient to Modern Times*, p.153.

[125] Ibid., p.153.

[126] Ibid., p.153.

[127] Ibid., p.153.

[128] David Bostock. *Space, Time, Matter and Form: Essays on Aristotle's Physics,* pp: 22-28.

boundaries of the given world. Aristotelian tradition in that regard, denied "the very possibility of a mathematical physics, on the ground of the unconformity of mathematical concepts to the data of sense-experience and of the inability of mathematics to explain quality and to deduce movement."[129] For the Aristotelian thought, the identity of the experienced world and the world of geometry is an unacceptable supposition.[130] "To isolate an object from its physical environment and to treat it with abstract mathematical concepts…is a worthless trial on the way to knowledge."[131] Therefore, for Aristotelians in dealing with concrete physical problems, it is necessary to take into account the world order and to consider the realm of being (the "natural place") to which a given body belongs by its nature.[132]

Accordingly, for Aristotle it is not mathematics that validates physical reality, but rather it is the necessities of the physical environment that dictate the choice between the various geometrical and mathematical models.[133] In other words, the authority of a mathematical construct or explanation is a matter of its compatibility with observed reality. Number and geometrical properties are also for him the properties of real objects. Distinct from the Platonic thought in which mathematical concepts have independent existence, Aristotelian conception of

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[129] Alexandre Koyré. *Metaphysics and Measurement,* Paris: Gordon and Breach Science Publishers, 1992, p. 6.

[130] Ibid., p. 6.

[131] Ibid., p. 6.

[132] Ibid., p. 6.

[133] Stanley I. Jaki. "Introduction" in, Pierre Duhem. *To Save the Phenomena: An Essay on the Idea of Physical Theory From Plato to Galileo,* Trans. Edmund Donald and Chaninah Maschler. Chicago and London: The University of Chicago Press, 1969, p. xxi.

mathematics depends on the fact that any mathematical entity is a property of the physical body which it is derived from.[134]

A further major achievement of Aristotle is the founding of the science of logic.[135] His application of logic to the science of physical objects remained unchanged till nineteenth century. Though Aristotle derived his science of logic from mathematics, further development of logics in his achievements came to be applicable to all reasoning. He declared that logical reasoning was independent of and prior to mathematics.[136]

2.2.2) The Value of Abstract Ideas and Sense Experience

The achievements of the Greek world under two traditions –the Platonic and the Aristotelian can be summarized as such: Mathematical concepts are started to be treated as abstractions. The abstractness and independence of mathematical concepts made them the ultimate sources of knowledge. On the one hand, perfection, ideality and accuracy of mathematical concepts and relations support the elevated role of mathematics in speculative thought; on the other hand, the timeless, immutable, universal character of mathematics made it the only source for the explanation of physical reality. The search for a mathematical design was identified with the search for truth. The predictive value of its methodology started to be applicable to all reasoning and the logic of scientific explanation was exactly set.

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[134] Morris Kline. *Mathematical Thought from Ancient to Modern Times*, p. 51.

[135] Ibid., pp: 52-53.

[136] Ibid., pp: 52-53.

All these achievements of the antique period reached their final form in Euclid's work: in his "*Thirteen Books*" geometry was established as a closed and complete system whose concepts and relations are accepted to correlate well with the physical space.[137] Euclid's mathematical implications were mainly the outcome of a methodical simplification and abstraction of observed phenomena.[138] This abstraction of common experience, Bell states, is one of the principal sources of the utility of mathematics and the secret of its scientific power.[139] Through this abstracting and simplifying of the evidence of senses, there came about a possibility for a rational description of the experiences that well accords with logical derivations.[140] In that respect, the work of Euclid can be considered as the first attempt to link *abstract logic* and *sensual experience*.[141]

> The great practical significance of this construction consisted in the fact that it endowed geometry with a certainty never previously attained by any other science. The small number of axioms forming the foundation of the system were so self evident that their truth was accepted without reservation. The entire construction of geometry was carried through by a skillful combination of the axioms alone, without any addition of further assumptions…*As he had reduced his geometric construction to a system of axioms; it became the prototype of a demonstrable science.*[142]

Though the main frame of Euclid's work consists of particularities, its completeness is a consequence of his deductive methodology. As Euclid started his construction with axioms and derived subsequent inferences from these basic

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[137] Hans Reichenbach. *The Philosophy of Space and Time*, p. 1.

[138] Morris Kline. *Mathematics in Western Culture*, p. 43.

[139] E. T. Bell. *The Development of Mathematics*, p. 9.

[140] Ibid., p. 9.

[141] Bernard Cache. "Plea for Euclid". *In* *http://architettura.superava.it/extended/19990501/index_en.htm* p.1. last accessed in 05.11.2006

[142] Hans Reichenbach. *The Philosophy of Space and Time*, p.1. (The order of words is changed in the sentences written italic.)

axioms, the initial step to a deductive science of space was set in its clearest form.[143] The apparent practical significance of this construction, Bell affirms, consisted in the fact that it endowed geometry with a certainty never previously attained by any other science.[144] Since the entire construction of geometry was carried through by a skillful combination of axioms alone, a geometric explanation of space was set without any addition of further assumptions.[145] Within this new system of geometric construction, the conception of space gained a new certainty and accuracy. The translation of observed qualities of space into systematic relation of geometric quantities considerably became the major contribution of the Greek period not only to mathematics but also to the fields that exist and function in space. In that respect, reservations of the Greek period turn out to be the most efficient and operative elements in the history of science and mathematics, which have also had significant reflections in architecture.

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[143] Ibid., p.1.

[144] Ibid., p.1.

[145] Ibid., p.1.

2.3) Mathematical Grounds of Architecture until the 19th Century

2.3.1) Greek Architecture: Theory of Proportion as the Basic Aesthetic Element

The relation between mathematics and architecture has been a long lasting subject in architectural tradition.[146] However, the belief in mathematically ruled design is accepted to have found its initial realization and reflection in architecture in the built examples of Greek temples and in the first written document of architectural history: *Ten Books of Architecture* by Vitruvius. Though in his treatise Vitruvius stated so many times about the relation between architecture and mathematics, its detailed manifestation is brought about in his theory of proportion. Through his definition of architectural theory, Vitruvius necessitated the significance of proportion and mathematical relations for the precision and dexterity of the work.[147] He conceived of the theory of proportion as a prerequisite for a detailed proportioning of each architectural element and for their exact and graceful arrangement according to the principles of symmetry.[148]

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146 Richard Padovan. "The Harmony of the World Made Manifest in Form and Number," in Richard Padovan. *Proportion: Science, Philosophy, Architecture,* London and New York: Spon Press, 2003. pp: 1-17.

147 Vitruvius. *The Ten Books On Architecture,* Trans. Morris Hicky Morgan, New York: Dover Publications, 1960, p. 5.

148 These prerequisites form the three fundamental concepts termed by Vitruvius as, *ordinatio, eurythmia and symmetria.* Hanno Walter Kruft explains these concepts as such; *ordinatio* is the detailed proportioning of each separate part of a building, and the working out of the general proportions with regard to *symmetria*; *eurythmia* implies an appearance that is graceful and agreeable in the way in which its individual elements are arranged; and *symmetria* is the harmony of arising out of the assembled parts of a building, and the correspondence of the separate parts to the form of the building as a whole in a fixed proportion. He than adds that these three concepts are different aspects of the same aesthetic phenomenon -that is; *ordination* might be described as the principle, *symmetria* as the result, and *eurythmia* as the effect. Hanno Walter Kruft. *A History of Architectural Theory from Vitruvius to Present,* Trans. Ronald Taylor, Elsie Callander and Antony Wood. New York: Princeton Architectural Press, 1994, p. 26.

However, while for Vitruvius, proportion is a necessity to acquire beauty in design, it is not a visual concept:[149] "It is purely a numerical relationship, not the effect arising from its application."[150] In that respect, as observed by Mark Gelernter, what lies behind Greek architecture's utilization of mathematical relations and proportions is the belief that there is or should be a distinction between "contingent matter" and the more "stable form behind it."[151] Since the properties of matter can only be seized through sense experience which is imperfect and deceitful, the underlying essence behind forms and formal creation is believed to be in the unchanging universal rules of nature that is thoroughly mathematical in character. As regards, for the Greeks, the search for universal rules and orders was a matter of obtaining "the knowledge of timeless form behind sensory experience."[152]

Accordingly, as stated by Hanno Walter Kruft, proportion has a tripartite manifestation in the Vitruvian treatise: (1) the relationship of the parts to each other, (2) the reference of all the measurements to a common module and (3) the analogy with the proportions of the human body.[153] It can be asserted that this tripartite manifestation of proportion brings to the fore two dominant approaches on the interpretation of Greek architecture's relation with mathematics: (1) the technical utilization of numeric and geometric relations as an aesthetic requirement and (2) the symbolic utilization of mathematics that interprets this relation as an embodiment of divine order in the body of architectural object.

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[149] Hanno Walter Kruft. *A History of Architectural Theory from Vitruvius to Present,* p. 27.

[150] Ibid., p. 27.

[151] Mark Gelernter. *Sources of Architectural Form: A Critical History of Western Design Theory.* Manchester and New York: Manchester University Press, 1995, p. 54.

[152] Ibid., p. 54.

[153] Hanno Walter Kruft. *A History of Architectural Theory from Vitruvius to Present,* p. 27.

From a technical point of view P. H. Scholfield's book *On the Theory of Proportion in Architecture* gives a detailed account of this relation, stating that the application of proportions in Greek architectural production was a matter of visual gratification.[154] For Scholfield, the remarkable power of proportional relations is related with the eye's detection of the same sizes and/or shapes and favoring of them.[155] Therefore for Scholfield, the aesthetic aspect of employing proportional relations associates with the use of modular objects or the objects produced in comparative sizes to each other.[156] As regards the theory of proportion, he declares, has enabled the Greeks to apply different proportional elements without fixing the architecture to absolute measurements.[157] Therefore, for him the significance of geometric proportions in Greek architecture lies in the possibility of offering a "mathematical layout" and a "methodological system" that is useful in practical investments.[158]

[154] P. H. Scholfield. *The Theory of Proportion in Architecture.* Cambridge: Cambridge University Press, 1958, p. 3.

[155] Ibid., p. 5.

[156] Ibid., p. 4.

[157] Ibid., p. 17.

[158] Ibid., p. 17.

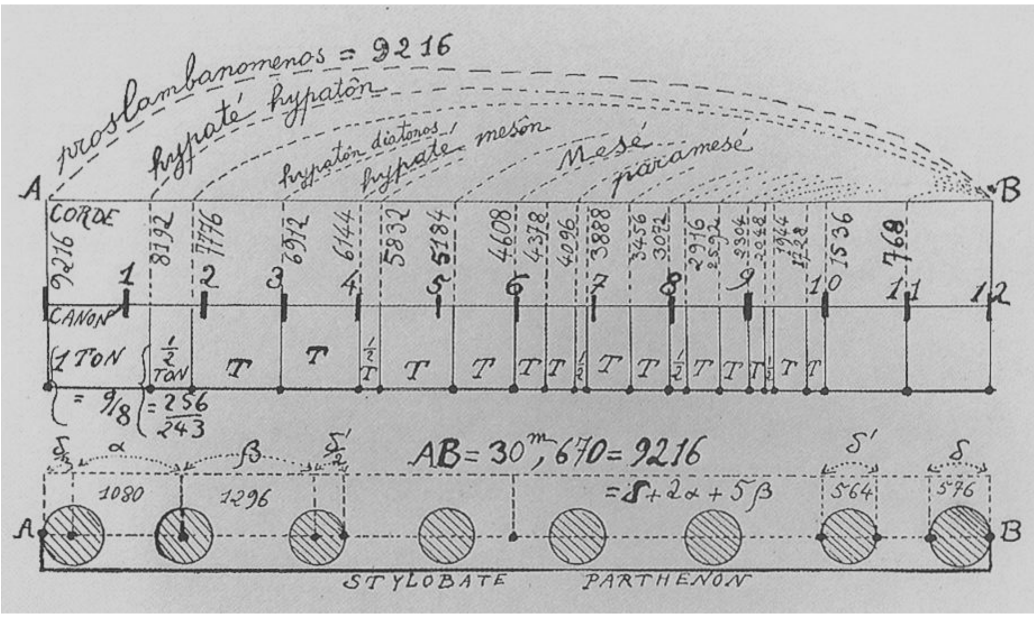

Figure 1.5: Planimetric layout of a Greek temple formed through a Pythagorean serial **Source:** Umberto Eco. *History of Beauty,* Trans. Alastair McEven, New York: Rizzoli International Publications, 2004.

As regards, geometric relations defined under the theory of proportion in Greek architecture were necessities for a faultless and accurate practice. In that respect, for the Greek period, it can be asserted that the practical utilization of geometry/geometric relations and proportions in architectural production has two major consequences: (1) the use of mathematical relations to form an operational layout provided exactness and accuracy in the architectural process and (2) since the rules were set in prior, the architectural process turned out to be a derivation of forms from initially set rules and the architectural production came out to be a successive confirmation of these rules that ends up with visual/perceptual beauty.

For the interpretations that focus on the symbolic aspect of Greek architecture's relation with mathematics and mathematical relations under the theory of proportion, the underlying purpose was undeniably an aesthetic concern. However the term aesthetic did not have the same connotations with the technical explanations of this relation. Rather than to establish numeric relations that please the eye, in its symbolic utilization, the "theory of proportion" is seen to provide for "ultimate harmony" and "absolute beauty."[159] As clearly stated in the Vitruvian treatise;

> One is the beauty which is close to hand, another that which is high above us; nor is the same valid for enclosure as for the open air, so that you need great ingenuity to take the right decision. The eyes, moreover, do not give a correct idea of things, but will deceive the mind in its judgments….Since things which might seem false are true, while the eye on the contrary, will accept things which are quite different from reality, I put it beyond doubt that something must be added or taken away according to the requirements and nature of their situation…and for this theoretic knowledge is not enough, but acute ingenuity is also required…First therefore the measure of the symmetries must be established, from which surely the modifications may be deduced; then the unit of the outer length is fixed on the site of the future building; once that size is fixed, there will follow the working out of proportions in such a way that observers will not have any doubt about its eurythmy.[160]

Distrust in sense experience/perception and the search for universal rules and orders in Greek architecture as observed by Dalibor Vesely, has its origin in the Pythagorean-Platonic tradition.[161] As the natural world is not comprehensible in its totality by means of perception, the task of architecture cannot or should not be a matter of establishing numeric relations for the eye itself.[162] Natural or physical reality is accepted to be beyond the limits of perception.[163] What can be perceived

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[159] Vitruvius. *The Ten Books on Architecture*, p. 175.

[160] Joseph Rykwert. *The Dancing Column,* Cambridge and Mass: The MIT Press, 1996, p.227. Originally in Vitruvius, *Ten Books on Architecture.* part: xi.

[161] Dalibor Vesely. "The Architectonics of Embodiment" in George Dodds and Robert Tavernor (Ed.) *Body and Building*, Cambridge and Mass: The MIT Press, 2002, pp: 36-37.

[162] Joseph Rykwert. *The Dancing Column,* p. 227.

[163] General assumptions/doctrine of Platonic tradition discussed in detail in the previous subchapter.

by the eye could only be a limited part of its reality.[164] The essence of physical reality which can only be explainable in mathematics therefore is believed to be the only source for architecture in its search for timeless, universal principles.[165] The symbolic analogy formed between the rules of nature that is mathematical in character and the architectural object is represented in Greek architecture in the theory of proportion suggesting that "behind the underlying proportion (and other summary notions such as universal beauty, order, and harmony) there is always present a deeper level of articulation, coextensive with the articulation of the world as a whole."[166]

> In the primary tradition, *analogia* is a symbolic structure that has nothing directly to do with numbers. It depends on resemblances, similarities, and eventually a balanced tension of sameness and difference when related to various phenomena. Thus the origin of proportion is not in mathematics, understood in the conventional sense, but in language, even when it is expressed numerically, it still depends for its meaning on language…The representation of proportion as number derives from the original form of analogy, and more specifically the tension between "the one and many" (identity and difference), which is the essence of metaphor.[167]

With respect to the symbolic analogy formed between the creation of cosmos from the One and the use of module as the basic element of proportion, Vesely states that the use of proportions or numeric relations in Greek architecture is

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[164] General assumptions/doctrine of Platonic tradition discussed in detail in the previous subchapter.

[165] Mark Gelernter. *Sources of Architectural Form: A Critical History of Western Design Theory,* p. 62.

[166] Dalibor Vesely. "The Architectonics of Embodiment" in George Dodds and Robert Tavernor (Ed.) *Body and Building*, p.37.

[167] Ibid., p.37.

assumed to reveal the image of divine order.[168] As the essence of this divine order is hidden in numbers, nature's true manifestation could only be revealed in mathematics and mathematical relations.

The analogy constructed between divine harmony and architectural order in that regard was based on detached similarities and relations between the two realms.[169] Yet, the structured/proposed analogy between architecture and cosmos is a vertical one, "the appraisal of a higher order appeared in architecture as an embodiment that represents a continuum of mediation between the human and divine, terrestrial and celestial, sensible and intelligible levels of reality."[170] However the apprehension of such kind of a similarity/relation is accepted to need a mediator to reveal or to make itself visible.[171] The human body or the body of the architectural object then turned out to be a medium for embodiment, in proportions of which it is believed that the harmony and beauty of the cosmos lie.[172] Becoming the conveyor of a higher order, the human body placed on a perfect circle and square gained a transcendental status in Greek architecture for the production of form and symbolic meaning.

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168 Richard Padovan. *Proportion: Science, Philosophy, Architecture.* London and New York: Spon Press, 2003.p.15

169 Dalibor Vesely. "The Architectonics of Embodiment" in George Dodds and Robert Tavernor (Ed.) *Body and Building*, p. 37.

170 Ibid., p.32.

171 Joseph Rykwert. *The Dancing Column,* p. 69.

172 Ibid., p. 69.

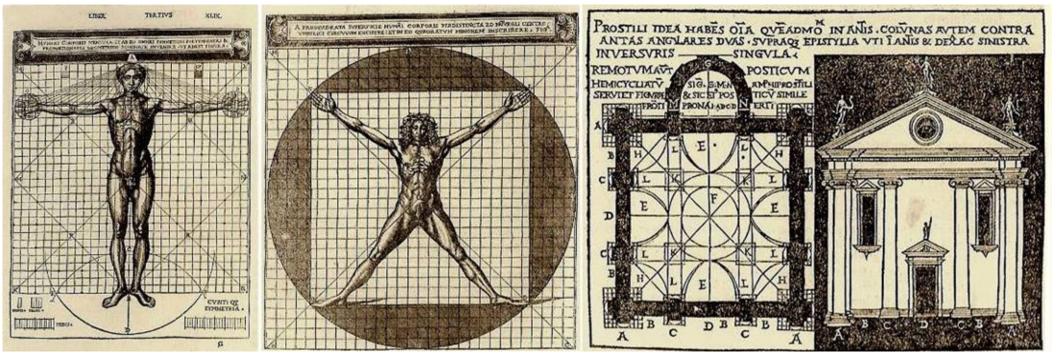

Figure 1.6: (1) *Homo ad quadratum,* Vitruvian man in a square, Vitruvius III, 1. P.XLI. (2) *Homo ad circulum*, Vitruvian man in a circle and in a square within the circle, P.L. (3) Reconstruction of the prostyle temple, **Source:** Architectural Theory. Köln: Taschen, pp: 30-31.

The unlimited, measureless, ephemeral character of nature was accepted to be comprehensible by the limited, intelligible and certain relations of mathematics.[173] Microcosm and macrocosm was assumed to possess the same unity, which finds its reflection in mathematics/numbers.[174] As regards, it can be asserted that numbers and mathematical relations had an undeniable significance for Greek architecture on behalf of the facts that: (1) they are the reason of goodness, beauty and truth, (2) they are the cause of all diversity, harmony and change and (3) dependent to anything they are the ultimate foundation of everything.[175] The validity of first or final causes of architectural proportions is out of questioning as the mathematical harmony of nature is an independent reality (of its own).[176] Therefore the independent/unconditioned rules belonging to a transcendent order turn out to be the source of architectural production and the application of these rules are taken for granted as either confirmation or appraisal of the order that is

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[173] Morris Kline. *Mathematics: A Cultural Approach*, p.15.

[174] Ibid., p.15.

[175] For an elaborate discussion of the subject see previous subchapter.

beyond the boundaries/domain of pure (practical) knowledge provided by mathematics.[177]

The genuine appraisal of mathematics as a practical instrument in architecture however came about with the Renaissance architecture through the application of perspectival methodology as a mode of representation. On the other hand, like the search for a rational theory of space in perspectival representation, the initial questionings on the foundation of architectural discipline necessitated again a grounding of the profession's principles in mathematics and mathematical relations. However neither in the search for a rational theory of space nor in the first explorations of architectural profession as an autonomous discipline, architecture's exact departure from mathematics' symbolic utilization was achieved. In that regard, mathematics and geometry being the utmost media and instruments of architectural production continued to be the main sources of architecture with reference to their symbolic relation with order, truth and meaning. The following sub-chapter will focus on the role of mathematics and geometry in the Renaissance architectural production with respect to the changes and continuations in its conceptions and practical utilizations.

2.3.2) Renaissance: the Objective Existence of Mind and the Mathematization of Space

According to Ackerman, the premises of Renaissance architecture can be asserted to have emerged from the questionings of the status and foundation of architecture

[177] Françoise Choay. *The Rule and the Model: On the theory of Architecture and Urbanism.* Ed. Denise Bratton. Cambridge and Mass: The MIT Press, 1997, p. 2, 20.

as a discipline/profession.[178] Under the influence of the newly founded academies, a systematic approach to architectural thinking and production had started to develop in 14th century. [179] The new learning taught in faculties of liberal arts under the four subjects of the quadrivium –arithmetic, geometry, astronomy and music, caused many transformations in the understandings of most study fields.[180] For these study fields knowledge attained by reasoning has started to be conceived as the only means to understand the working principles of the physical world.[181]

Besides the acceptance of the authority of reasoning as the only means in studies of the physical world, the application of logics to the subjects of the quadrivium gave rise to the most essential change in the methodologies of these disciplines resulting in a new systemic approach on the investigations of various fields.[182] The organizing principles of the methods of logical analysis and their methodological clarity elevated the role of the mind in achieving the most proper knowledge about the physical world. Any field, whose subject is within the boundaries of the visible world, has assumed to depend on the knowledge provided only by the mind. These developments, initially on the methods then on the boundaries of the subjects of the quadrivium, re-shaped the system, role and status of most disciplines. By far, the quadrivium started to function as the source of both theoretical and practical knowledge for the majority of disciplines

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[178] James S. Ackerman. "Architectural Practice in the Italian Renaissance," *Journal of the Society of Architectural Historians*, No: 13, October, 1954: 3-11, p. 3.

[179] Ibid., p. 3.

[180] Edward Grant. *The Foundation of Modern Science: Their Religious, Institutional, and Intellectual Contexts.* Cambridge: Cambridge University Press, 1996, p. 43.

[181] Edward Grant. *Science and Religion, 400 B.C. to A.D. 1550: From Aristotle to Copernicus.* London: Greenwood Press, 2004, p. 181.

[182] Ibid., p. 151.

including architecture.[183] Consequently, architecture under the influence of the transformations and developments in different systems of thoughts, entered a renewal procedure on the basis of its sources, foundations and processes. As regards, Choay states that it was for the first time with the Renaissance thought that the boundaries of architectural practice and theory were set devoting an autonomous discursive domain to the organization of built space.[184]

However, for most disciplines as architecture, the main source of this renewal was in the antique texts translated from Arabic cultures.[185] As regards, the knowledge attained with the translation of Euclid's, Aristotle's, Plato's texts formed the ultimate basis of the transformation in the philosophical and scientific tradition. This new appearance of the writings of significant figures of the antique period therefore had an essential contribution on the changing paradigms of the period. Departing from scholastic thought, this new approach put emphasis on reason and the knowledge attained by reasoning.

[183] Edward Grant. *The Foundation of Modern Science: Their Religious, Institutional, and Intellectual Contexts*, p. 44.

[184] Françoise Choay. *The Rule and the Model: On the Theory of Architecture and Urbanism,* p. 6.

[185] Edward Grant. *The Foundation of Modern Science: Their Religious, Institutional, and Intellectual Contexts*, pp: 22-23

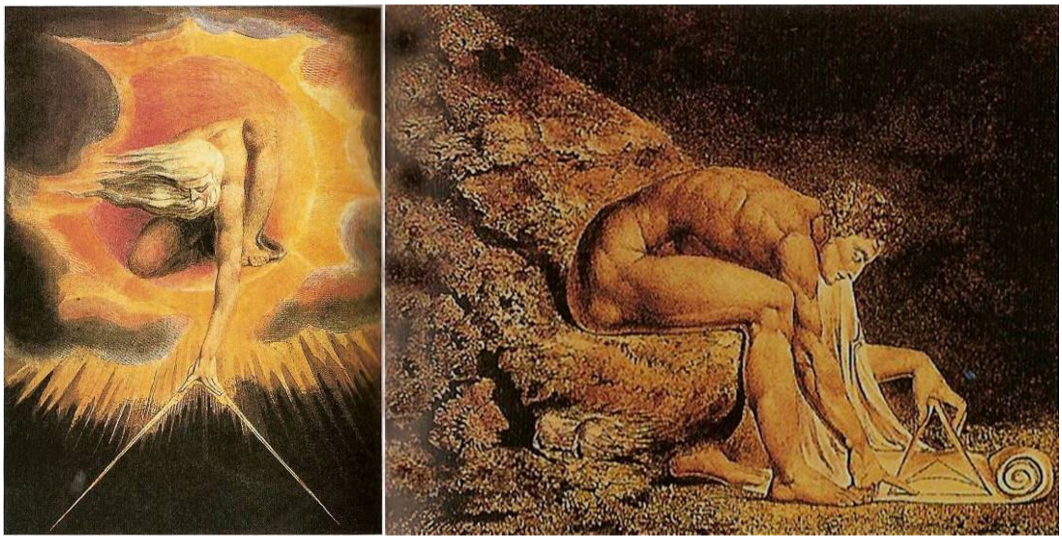

Figure 1.7: William Blake. *Europe* (God creating the mute sphere) and *Newton* (Newton experimenting nature with the tool that God created universe). **Source:** Alexander Roob. *The Hermetic Museum: Alchemy & Mysticism.* Köln: Taschen, 2006, p. 510-511.

All these developments went in hand with a raising interest in the texts of Aristotle. His approach to nature and its mechanism had rigorously influenced the investigations of Renaissance philosophy, science and astrology.[186] Nature turning into an object of scientific explanation was freed from its transcendental connotation.[187] Since any authority was seen increasingly to be misleading and unreliable, alternative philosophical systems had started to be threatened to overwhelm the pursuit of knowledge.[188] As stated by John Henry, "one profound

[186] Allen G. Debus. *Man and Nature in the Renaissance,* Cambridge: Cambridge University Press, 1981, p. 3.

[187] Though for some texts, God was still the initial cause of all physical phenomena; the explanation of nature was believed to be done with logics. It is mainly a result of the belief that any logical explanation will not contradict with the existence of God –since God is also a logical creator. This kind of a consideration can explicitly be seen in works of both Descartes and Leibniz.

[188] John Henry. *The Scientific Revolution and the Origins of Modern Science*. New York: Palgrave, 2002, p. 12.

change which emerged out of this was a greater emphasis upon discovering truth for oneself as a result of one's own experiences and efforts."[189]

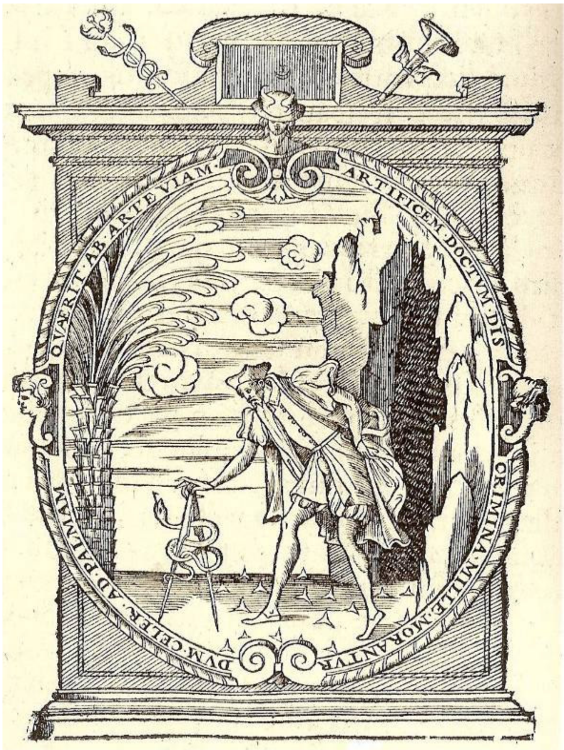

Figure 1.8: An engraving by De l'Orme that illustrate "the architect's path from the medieval cave to the palm of the new age." **Source:** *Architectural Theory*. Köln: Taschen, P. 128.

Architecture under the influence of the raising interest in Aristotelian thought gained a new definition which is explicitly revealed in Albertian texts. As observed by Vasari, under the influence of the general conjuncture of the era - which is apparently Aristotelian in its focus on perceptual faculties and the knowledge attained by them, Alberti directed his attention on the intrinsic

[189] Ibid., p. 12.

structure of the physical reality as appeared to the eye of the observer.[190] This inner structure of which the external appearances all depend has to be an order of mathematical kind for Alberti who believed in the utmost character of geometrical universe.[191] Consequentially, as stated by Vasari, Alberti, deemed to treat nature as a whole, that is, as figures and objects in their mutual relation on the basis of a mathematical science.[192] For Alberti it is nothing other than geometry which holds everything under the unification of one system. Taking the aspect of visibility as the common ground for coalescence, perspective as a method of representation provided the architects with the universal language.[193]

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[190] Baldwin Brown. Introductory Essay. In, Giorgio Vasari. *Vasari on Technique,* Trans. Louisa S. Maclehose. New York: Dover Publications, 1960, p. 13.

[191] Leon Battista Alberti. *On Painting,* Trans. John R. Spencer. New Haven and London: Yale University Press, 1966, p. 72.

[192] Baldwin Brown. Introductory Essay. In, Giorgio Vasari. *Vasari on Technique,* p. 13.

[193] Ibid., p. 13.

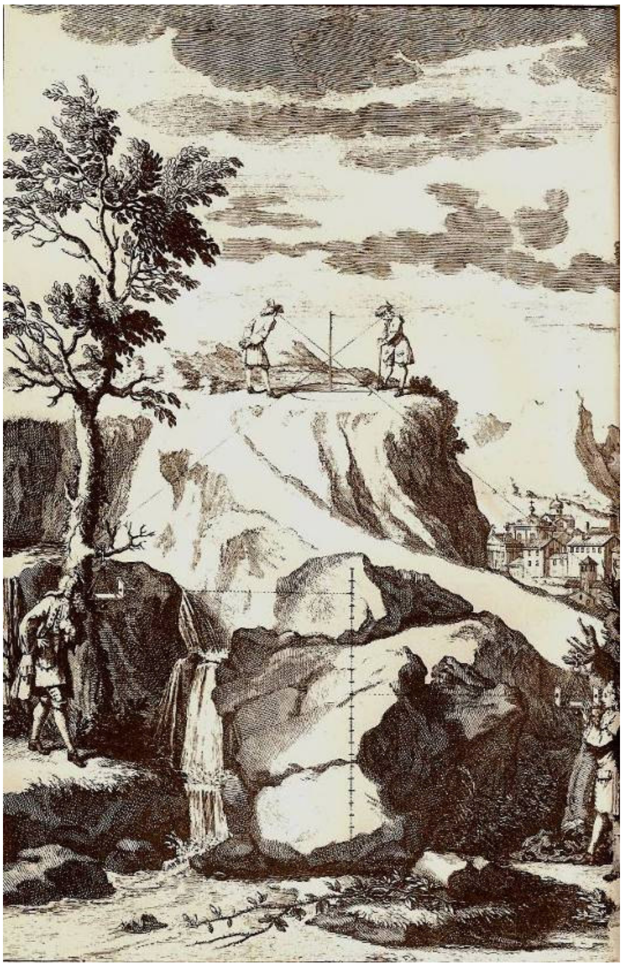

Figure 1.9: Man experimenting the geometric world order through observation, **Source:** Leon Battista Alberti. *The Ten books on Architecture.* Eds. Joseph Rykwert, London: 1955, New York: 1986, appendix.

Whereas the translation of Aristotelian texts prompted the raising interest on nature and the application of logical analysis methods to different fields of knowledge, the translation of Platonic and Neo-Platonic texts had given way to a revival of the mathematical interpretation of the physical world. However, translation of the most antique texts came about with their mystical implications.[194] According to Debus, this was most probably or specifically

194 Allen G. Debus. *Man and Nature in the Renaissance,* p. 11.

because of the hermetic tradition that re-emerged besides the interpretation of the antique texts -above which stands the writings of Plato.[195] Although, the new interest in mathematics on the one hand, "furthered the development of mathematical approach to nature and the internal development of geometry and algebra, on the other hand, the same interest resulted in occultist investigations of all kinds related to number mysticism."[196] The special importance given to mathematics was a result of the significance ascribed to quantification in Renaissance thought, however the occult influence of hermetic ideas had a much deeper impact than a quantified theory for most disciplines including architecture.[197] This was mainly a result of the belief in the unity and harmony of nature as revealing the unity and harmony of God: Under the influence of Christian thought not only the nature/cosmos was accepted to be the prevailing agents of divine order but also man was believed to be an intermediary medium for the appraisal of His supreme dignity.[198] This was well accorded with the Protagorean aphorism that "man is the measure of all things".[199]

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[195] Ibid., p. 11.

[196] Ibid., p. 11.

[197] Ibid., p. 11.

[198] Ibid., p. 12.

[199] Antony Gottlieb. *The Dream of Reason: A History of Philosophy from the Greeks to the Renaissance,* p. 120.

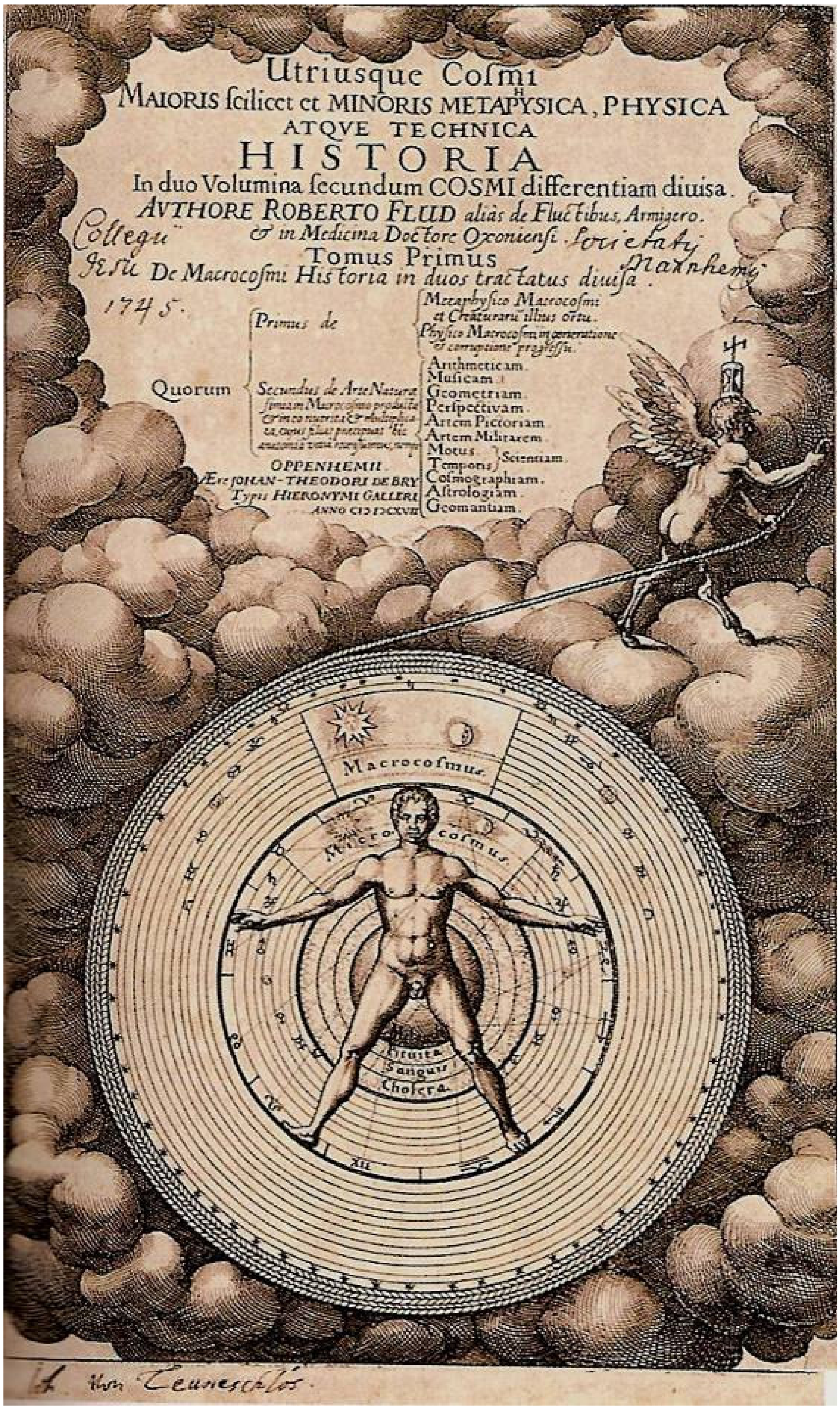

Figure 1.10: Roberto Flud. *Utrisco Cosmi*. Man at the center of the creation of microcosm and macrocosm. **Source:** Alexander Roob. *The Hermetic Museum: Alchemy & Mysticism,* Köln: Taschen, 2006, p. 437.

Renaissance architecture in that regard represents the resolution of the Greek's mathematical interpretation of nature in Christian belief -that "Man is the image of God."[200] As it is accepted that God created man as a reflection of its own image, the proportion of his body is assumed to be a manifestation of divine harmony.[201] The agreement on the belief that man is the ultimate reflection of God, Rykwert declares, is mainly a result of the "change on the understanding of the degrees and chains of being."[202] It is essentially a declaration of the fact that there is no proportional relation possible between finite and infinite, between the world and God.[203] Therefore the only way of attaining the knowledge of God is through analogic relations, which denote a similarity or even likeliness between man and his Creator.[204] Such an analogy between body and divine order, which is echoed in parallel between body and architectural orders, Rykwert states, is deeply ingrained in all examples of recorded architectural thinking.[205] Body, as regards is assumed to be the utmost model of divine order and magnificent design, as body's absolute beauty is idealized in architecture as an indication of harmony, unity and perfection.[206]

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[200] Joseph Rykwert. *The Dancing Column: On Order in Architecture,* p. 83.

[201] Ibid., p. 83.

[202] Ibid., p.83.

[203] Ibid., p.83.

[204] Ibid., p.83.

[205] Ibid., p. 29.

[206] Ibid., p. 29.

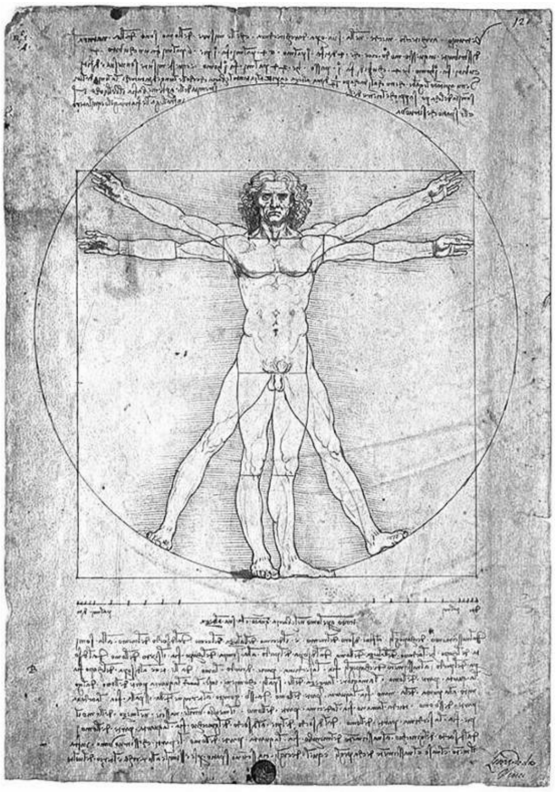

Figure 1.11: Leonardo da Vinci. Vitruvian human figure from the *Canone de Proporzioni*. **Source:** Mark Gelernter. *Sources of Architectural Form: A Critical History of Western Design Theory,* Manchester and New York: Manchester University Press, 1995, p. 64.

Since human body became the supreme conveyor of the Creators perfection and utmost portrayal of the harmony of the universe, in Renaissance architecture, the Vitruvian figure inscribed in a square and a circle became a symbol of the mathematical sympathy between microcosm and macrocosm.[207] The idea of the human body as microcosm was also transferred to building practice in which a temple or even a building was accepted to be a microcosmic revelation.[208] The symbolic implication of Vitruvius's demonstration of the human figure that well

[207] Rudolf Wittkower. *Architectural Principles in the Age of Humanism.* London: Alec Tiranti, 1962 (first published in Warburg Institute in 1952), p.16.

[208] Joseph Rykwert. *The Dancing Column,* p. 77.

fits to the perfect geometries of the circle and the square, therefore turned out to be an undeniable source for the Renaissance architectural production.

The revival of this Antique visual illustration in Renaissance architectural theory however, came about with its occultist connotations. The ideal proportions and perfect geometric relations embedded in the Vitruvian human figure are accepted to be the common measure of everything in the world.[209] The idealized human figure in that respect became the most essential representation of the mathematical and geometric order of the nature in the appearance of which God reveals his divinity and perfection. As man is assumed to be the symbol of perfection, the next step is the deduction of geometries, namely of the perfect circle and the perfect square without which it is impossible to achieve anything.[210] In support of the belief that nature enjoys the round form above others, Wittkower states, the superiority given to the circle is one of the most evident examples of a eulogic approach to some basic shapes and their usage in most sacred buildings.[211]

Consequently, the use of some privileged shapes in church design is seen to be the reflection of God and its perfection.[212] Taking its roots from the neo-Platonic and Pythagorean philosophy, the circular plan and its center are regarded as the symbols of God.[213] The ultimate source of the planimetric arrangement of a church and its further extrusion in the vertical direction was the Vitruvian human figure with its geometrical layout and proportional relations.[214] Taking into

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[209] Rudolf Wittkower. *Architectural Principles in the Age of Humanism*, p.15.

[210] Ibid., p.15.

[211] Ibid., p.3.

[212] Ibid., p.12.

[213] Ibid., p.13.

[214] Ibid., p.7.

account the ultimate harmony and unity of the human figure, Alberti defines beauty as “a rational integration of the proportions of all the parts of a building in such a way that every part has its absolutely fixed size and shape and nothing could be added or taken away without destroying the harmony of the whole.”[215] For Alberti, not less important than the perfect arrangement of architectural elements, the exact depiction of the achieved unity had also a significant role. This motivation therefore resulted in the first trials of perspectival representation.

The translation of the texts of Euclid, like the other books on optics, caused a turn in attention on the visual process and mechanism of seeing.[216] The influence of optical treatises that re-appeared in early Renaissance also triggered the rise of Aristotelian thought that sees sense experience as the ultimate source of knowledge.[217] Vision in that respect as the most important sense of direct knowledge was accepted as the utmost medium of the “common sensible.”[218]

Under the influence of these stimuli, the exact demonstration of an architectural product for architects came to be the most essential target.[219] The most significant component of this will however, was the perfect depiction of what is

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[215] Ibid., p.7.

[216] David Lindberg. “Alhazen’s Theory of Vision and Its Reception in the West,” *Studies in the History of Medieval Optics,* London: Variorum Reprints, 1983, pp: 330-333.

[217] David Lindberg and Nicholas Steneck. “The Sense of Vision and the Origins of Modern Science” in; David Lindberg. *Studies in the History of Medieval Optics,* London: Variorum Reprints, 1983. Originally published in; Science, Medicine and Society in Renaissance. Essay to Honor Walter Pagel, ed. Allen Debus, Vol.I. New York: Science History Publications, 1972, p. 33.

[218] Ibid,. p. 35.

[219] James S. Ackerman. *Distance Points: Essays in Theory and Renaissance Art and Architecture,* Cambridge, MA: The MIT press, 1991, p. 62.

seen/imagined in its total ideality.[220] Hence, what forms the most basic endeavor of this relation was the desire to translate the subjective act of seeing into an objective method of depiction.

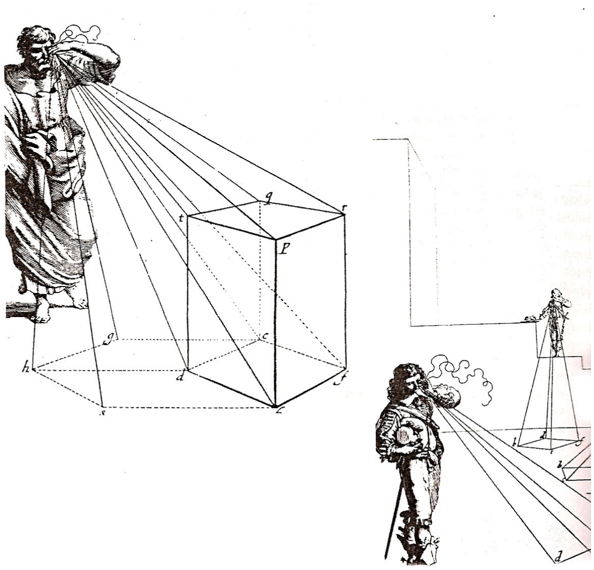

Figure 1.12: *Les Perspecteurs,* from Abraham Bosse's *Manière universelle de Mr. Desargues (1648).* Depictions that illustrate the belief in the power of perspective as a universal method to configure and construct the world **Source:** Alberto Pérez-Gómez and Louise Pelletier. *Architectural Representation and the Perspective Hinge,* Cambridge, MA: The MIT Press, 1997, p. 70.

Grounding all his theory of "good architecture" on the observation of the natural order, Alberti founded the initial attempts to externalize the theory of architecture from practical concerns. This unconditioned trust on the significance of observational knowledge made him focus on developing an objective, universal technique both to reveal his investments on visual, physical order and to share them.[221] Alberti, in regards, set the initial steps for an objective method of

[220] Ibid., p. 62.

[221] Erwin Panofsky. *Perspective as Symbolic Form.* New York: Zone Books, 1991, p. 65.

representation in his description of the perspectival construction. Depending on the mechanism of seeing, he repeatedly referred to the "pyramid" of vision, a section of which forms the picture plane.[222]

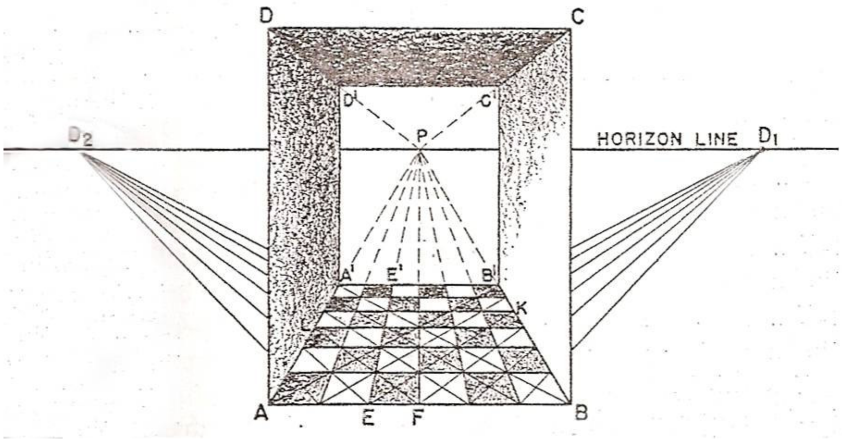

Figure 1.13: Alberti's perspective construction, **Source:** Morris Kline. *Mathematics in Western Culture*. New York: Oxford University Press, 1959, p. 137.

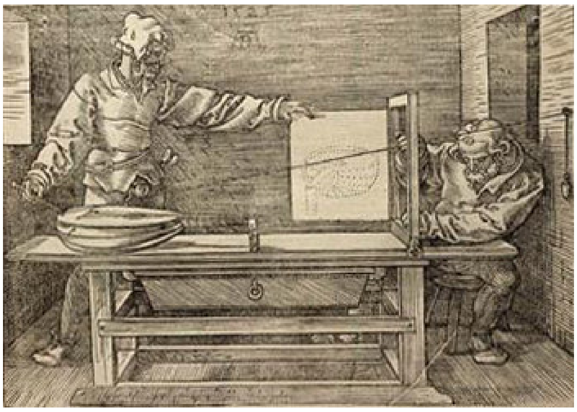

Figure 1.14: Albrecht Dürer, Perspective setup, **Source:** Morris Kline. *Mathematics in Western Culture*. New York: Oxford University Press, 1959, pp: 134-136.

222 Judith Veronica Field. *The Invention of Infinity: Mathematics and Art in the Renaissance*, Oxford: Oxford University Press, 1997, p. 26.

Consequently, the intrusion of perspectival representation devalued any other method of non-systematic depiction, since the method of perspective was started to be seen as the only legitimate construction as understood from its later designation as "*contruzione legittima*".[223] As Ervin Panofsky claims, it moreover became a novel step in conceiving space as a "*quantum continuum*".[224] Space with the advent of perspectival construction he notes, became a "continuous quantity" and as a result "a homogeneous entity consisting of three physical dimensions, existing by nature before all bodies and beyond all bodies, indifferently receiving everything."[225] Perspective, in that respect for him is not only a mathematical expression of space; but also, more central than this, an agent for ordering the visual phenomenon.[226] It is a transformation of reality (*ousia*) into an appearance (*phainomenon*) and therefore "a reduction of divine to mere subject matter of human consciousness."[227]

Though not utilized in the early periods of the Renaissance, after the fifteenth century, the idea of geometric *lineamenti*, (perspectival or orthographic projection) became the most effective implement of architectural production.[228] Assumed to have the capability to transform the architectural idea into an objective information,[229] projective drawings gained a new status of authority.

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[223] Ibid., p.30.

[224] Erwin Panofsky. *Perspective as Symbolic Form.* p. 44.

[225] Ibid., p.66.

[226] Ibid., p.71.

[227] Ibid., p. 72.

[228] Alberto Pérez-Gómez and Louise Pelletier. *Architectural Representation and the Perspective Hinge,* Cambridge, MA: The MIT Press, 1997, p. 9.

[229] Robin Evans. "Architectural Projection," in *Architecture and Its Image: Four Centuries of Architectural Representation, Works from the Collection of the Canadian Centre for Architecture*, Montreal: Canadian Centre for Architecture, 1989, p. 19.

However, as the geometrization of the pictorial depth was not yet systematized in its totality, it did not immediately influence neither the experience of the world, nor the process of architectural creation.[230] As observed by Perez Gomez and Louise Pelletier, this is mainly because of the fact that "it was impossible for the Renaissance architect to conceive that the truth of the world could be reducible to its visual representation, a two dimensional diaphanous section of the pyramid of vision."[231] As regards the perspectival representation was remained to be conceived merely a depiction of the ontological continuity between the physical realm and the absolute supra-lunar realm of the divine.[232] In that respect, as Perez Gomez and Louise Pelletier further add, "from the fifteenth century to the late seventeenth century, the disclosure of mathematical truths in discourse was still mostly a contemplative "practice" preoccupied with revealing a space of ontological continuity."[233]

Mathematics' detachment from its ontological roots however came about with Descartes' formulation of mathematical thought. Believing on the fact that mathematics transcends its subject matter, he set a new conception of mathematics that is truly a human construct and the most powerful instrument of knowledge.[234] His acknowledgement of mathematics as a superior mode of knowledge in that regard, initiated the first steps of the formulation of his thoughts on space around

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[230] Alberto Pérez-Gómez and Louise Pelletier. "Architectural Representation Beyond Perspectivism." *Perspecta*, Vol. 27, 1992, p. 24.

[231] Ibid., p. 24.

[232] Alberto Pérez-Gómez and Louise Pelletier. *Architectural Representation and the Perspective Hinge,* p. 23.

[233] Ibid., p. 33.

[234] Stephen Gaukroger. *Descartes' System of natural Philosophy.* Cambridge: Cambridge University Press, 2002, p. 8.

universal principles that are thoroughly mathematical.[235] However his conception of mathematics as a new method of operative science set a new departure point from the obscurities of algebra and Greek geometry. For Descartes, either Greek geometry (for being tightly bound to the imagination) or algebra (for being too abstract to exercise with) cannot have a universality claim.[236] By far, his expression of space through three dimensions and his definition of spatial objects through the points of this coordinate system provided him the desired quantification and ease. By means of this new method, which is later termed as the *Cartesian coordinate system,* geometric concepts could easily be translated into algebraic formulas.[237] This innovative methodology therefore, provided a new conception of space that is exact, quantitatively continuous and homogeneous.[238] Because of its accuracy in metric relations and due to the determinant character of the spatial relations, Cartesian space became the sole model for architects to operate in. However for a long time architects, though practically operating within this rational system, did not conceptually/theoretically establish a departure from mathematics' symbolic, metaphoric or even transcendental implications.[239] The exact departure of architectural production from its transcendental roots was going to be accomplished later with nineteenth century developments.

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[235] Ibid., p. 100.

[236] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 308.

[237] Ibid., p. 322.

[238] Erwin Panofsky. *Perspective as Symbolic Form*, p.70.

[239] For further information about the subject see; Erwin Panofsky. *Perspective as Symbolic Form,* New York: Zone Books, 1991; Martin Jay. *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought*, California: University of California Press, 1994; Martin Jay. "Scopic Regimes of Modernity" in *Vision and Visuality,* Ed: Hal Foster, Seattle: Bay Press, 1988, pp: 3-27; Jonathon Crary. "Modernizing Vision," in *Vision and Visuality,* Ed: Hal Foster, Seattle: Bay Press, 1988, pp: 29-44.

In that regard, the following pages will focus on the initial attempts in the construction of modern science and its unavoidable effects in architectural theory. In this brief survey on 17th century developments, the main focus will essentially be on architecture's raising questions of its foundations and sources.

2.3.3) 17th Century Architecture: The Rise of Empiricism and Observation

Although Renaissance architecture had turned its way to new sources of knowledge such as nature, reason and mathematics, it stayed insufficient in exploring them through a specific, unified method/theory of positive truth.[240] If the general explanation of physical phenomena was geometrical in Renaissance thought, the method of its revelation was not more than an "absolute image" provided by the technique of perspective.[241] In its positioning of man at the center of all external reality, the method of perspectival representation was the essential model of the general philosophy and science of the period.[242] In that respect, as noted by Martin Jay, while providing the externalization of physical reality by means of locating it at a distance from the subject, the Renaissance "perspectival philosophy" established man as the only true reality of all knowledge.[243] Indeed, specifically with the philosophy of Descartes, Jay claims, the reality of physical

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[240] Morris Kline. *Mathematics in Western Culture,* p. 126. Kline states that though renaissance art and architecture widely utilized mathematics and geometry, the underlying aim was just to represent nature realistically. He further adds that the utmost endeavor of the renaissance artist and architect was to reproduce the harmonious image of nature as seen by the eye.

[241] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science,* p.89.

[242] Martin Jay. *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought*, California: University of California Press, 1994, pp: 54-82.

[243] Ibid., p.55.

domain (*res extensa*) became a mere extension of man and his mind (*res cogitans*).[244]

However, the Galilean revolution prescribed a radical transformation on this privileged position of man which has reached its peak point with Cartesian philosophy.[245] Rejecting the geocentric system of cosmological order and the undeniable centrality of Earth in it, this new science set by Galileo accepted the universe as a whole comprised of common elements and governed by the same universal laws.[246] Henceforth, Earth became the subject of the new science whose notion is to expose the underlying principles and orders of physical reality. Alexandre Koyré figures out this revolutionary attitude by two complementary features: (1) the destruction of the hierarchical cosmological conception of the universe and consequently the disappearance of all the considerations based on this concept from the framework of science and (2) the mathematization of the universe in its all concreteness and continuity.[247] Koyré further adds that;

> The disappearance –or distraction- of the cosmos means that the world of science, the real world, is no more seen, or conceived, as a finite and hierarchically ordered, therefore qualitatively and ontologically differentiated, whole, but as an open, indefinite, and even infinite universe, united not by its immanent structure but only the identity of its fundamental contents and laws; a universe in which, in contradistinction to the traditional conception with its separation and opposition of the two worlds of becoming and being, that is, of the heavens and the earth, all its components appear as placed on the same ontological level; a universe in which the *physica coeletis* and *physica terrestris* are identified and unified,

[244] Martin Jay. "Scopic Regimes of Modernity" in *Vision and Visuality,* Ed: Hal Foster, Seattle: Bay Press, 1988, pp: 9-20.

[245] Louis Dupré. *The Enlightenment and the Intellectual Foundations of Modern Culture,* New Haven and London: Yale University Press, 2004, p.43.

[246] Richard S. Westfall. *The Construction of Modern Science: Mechanism and Mechanics.* Cambridge: Cambridge University Press, 1977, p.15-16.

[247] Alexandre Koyré. *Newtonian Studies.* London: Chapman & Hall. 1965, p. 6.

in which astronomy and physics become interdependent and united because of their common subjection to geometry.[248]

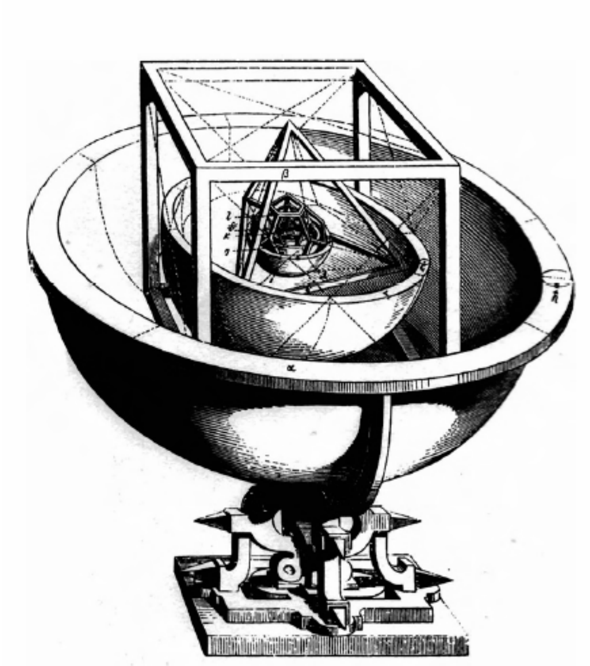

Figure 1.15: Kepler's model of the universe composed of Platonic Solids. **Source:** Robert Lawlor. *Sacred Geometry: Philosophy and Practice*, London: Thames & Hudson, 2002, p. 106

Rejecting chiefly the Aristotelian or namely the pre-Galilean conception of natural philosophy, this new science contented on the very possibility of mathematical physics which firstly assumes a conformity of mathematical concepts to the data of sense experience and second an ability of the mathematics to explain quality.[249] As regards, still under the influence of Platonic view, the foremost philosophers of modern science unquestionably accepted the privileged role of mathematics in the explanation of physical phenomena. Accordingly mathematics became the chief

[248] Ibid., p. 7.

[249] Ibid., p.5.

source of investigations on nature, the order of which could only be achieved by experiments.[250]

This new method of investigation manifested by the mathematical and scientific works of the seventeenth century, not only favored the role of "reason" in revealing the order of the universe but also cleansed the metaphysical and theological presuppositions of the classical period.[251] Reason applicable to all properties of the physical world, was seen to be the fact of each and every one of matter in motion.[252] Correspondingly, matter was accepted to be the sole reality of the physical phenomena which were governed by mathematical laws. The science of matter in that respect became the essential study field of the period stating that the whole physical order could be reducible to *matter* and *motion* and were completely explicable in terms of these two concepts.[253]

In that regard, the idea of nature became an independent entity, the very fact of which could be grasped by the mind through experience.[254] This recent engagement of the "mental" and the "experiential" did not only become a challenge for the scientists such as Bacon and Newton, but also for the philosophers of time i.e. Locke, Hume and Kant.

Philosophers of the era tried to reveal the interdependent relation between mind and objects. They inferred general principles from experience, and did not presuppose an ultimate metaphysical foundation for them. In denial of the initial

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[250] Ibid., p.vii.

[251] Morris Kline. *Mathematics in Western Culture,* p. 243.

[252] Ibid., 243.

[253] Morris Kline. *Mathematics: A Cultural Approach*, p. 445.

[254] Morris Kline. *Mathematics in Western Culture,* p. 246.

metaphysical foundation, the general explanation of physical phenomena was started to be given in causal link.[255] Reversing the relation previously ascribed by the classical period between mathematics and science, the philosophers of the era preferred quantitative axioms and mathematical deduction for the explanation of the "final causes".[256]

Newton was the first philosopher of the era who made a quite significant distinction between the final causes of a phenomenon and the particular mathematical laws derived from quantitative observation.[257] Discarding the autonomous formal character of scientific discourse, he established geometry and mathematics as practical subjects for the explanation of the mechanical structure of the universe.[258] The modern science of Newton in that respect could be said to have replaced the philosophy of the classical era. This shift, Pulte claims, resulted in a growing independence of mathematical physics from the philosophical foundations of its principles whether they are "empirical" or "rational".[259] What became exceptionally important in the course of eighteenth century philosophy, he claims, is the "deductive power of principles rather than their empirical contents, their axiomatic status rather than their status as "laws of nature", their formal truth rather than their material truth."[260] The great success of Newtonian science therefore is accepted to lie in its rejection of the speculative deductive

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255 Bertrand Russell. *History of Western Philosophy,* p. 604.

256 Louis Dupré. *The Enlightenment and the Intellectual Foundations of Modern Culture,* p. 20.

257 Ibid., p. 20.

258 Ibid., p.25.

259 Helmut Pulte. "*Order of Nature and Orders of Science*" in Wolfgang Lefèvre. *Between Leibniz, Newton and Kant: Philosophy.* Boston: Kluwer Academic Publishers, 2002, p.75.

260 Ibid., p.75.

metaphysical system of seventeenth century as well as in its refusal of the hypothetical assertions of reality.[261]

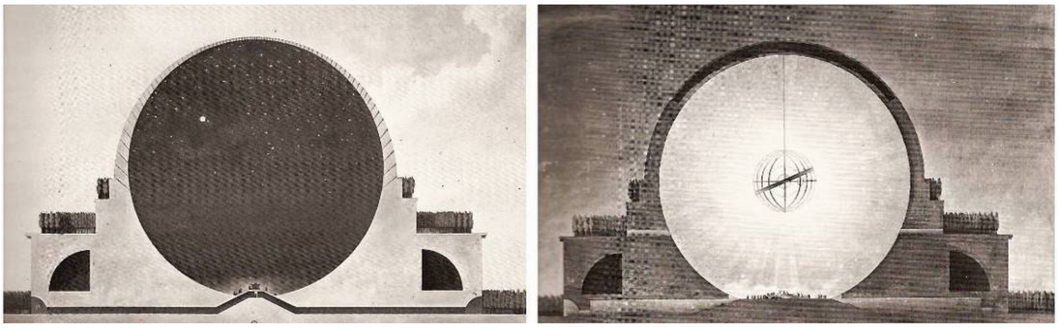

Figure 1.16: Newton Cenotaph by Boullé, **Source:** Anthony Vidler. *Ledoux: Architecture and Social Reform at the End of Ancien Régime*. Cambridge and Massachusetts: The MIT Press, 1990, p. 275.

The reflection of these developments in the natural science of the period was the decline of metaphysical discussions and the rise of the deductive organization of physical reality with reference to appropriate mathematical techniques.[262] Accordingly, the startling unification of the mathematical and the empirical in natural philosophy gave rise to a paradigmatic shift in epistemology. The systematization of the knowledge through observed data devalued the privileged role of speculation over observation and mere theory over practice.

[261] Andrew Janiak. "Introduction," in Isaac Newton. *Philosophical Writings.* Ed. Andrew Janiak, Cambridge: Cambridge University Press, 2004, p. xxv.

[262] Helmut Pulte. "*Order of Nature and Orders of Science*" in Wolfgang Lefèvre. *Between Leibniz, Newton and Kant: Philosophy,* p.75.

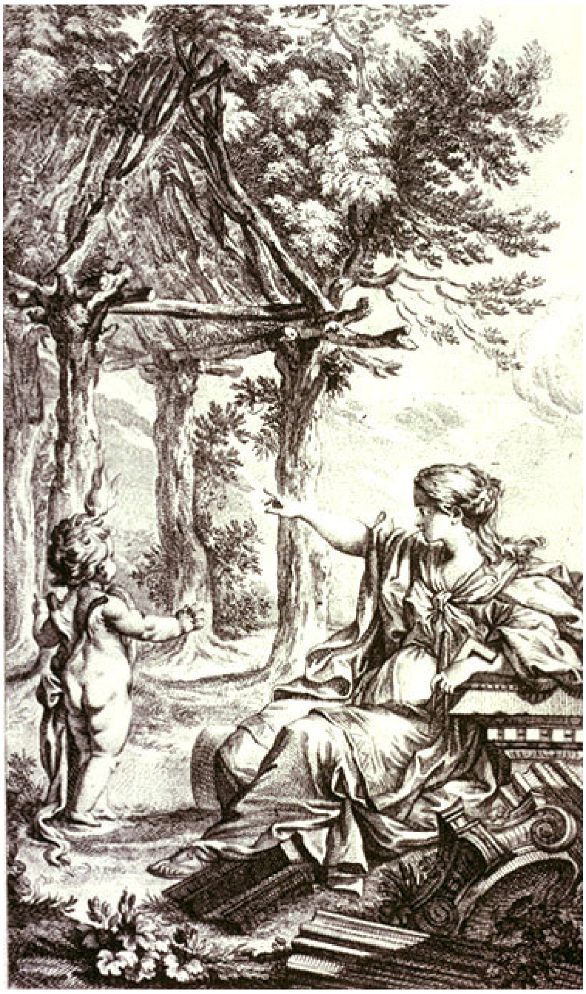

Figure 1.17: The primitive hut by Laugier as the source of architectural principles, **Source:** Alberto Perez Gomez. *Architecture and the Crisis of Modern Science.* Cambridge, MA: The MIT Press, 1983, p. 63.

These profound changes in the seventeenth century philosophy and science had also affected the architecture of the period. Explicitly revealed in the general theory of François Laugier, nature became the chief reference of architectural production. With his concept of "primitive hut" Hanno Walter Kruft asserts that Laugier's theory made the first call for an architecture with fixed rules that is in close relation with nature.[263] Considerably, taking into account the basic elements of primitive hut, that is, column, entablature, and pediment, Laugier set his concept as the origin of all possible forms in architecture.[264] Nature in process, in that regard, happened to be the chief model for the architects. As the science and philosophy of the era are in search for the basic principles of a geometrized nature, the architecture of the seventeenth century under the influence of these two disciplines was in trial of uncovering its essential rules of formal generation.[265] Architects, engineers and philosophers of the Enlightenment explicitly identified the principles of architecture with those of natural philosophy, prescribing a correspondence between the methods and sources of scientific investigation and architectural practice in belief of a parallelism on the achievement of truth.[266] As observed by Perez Gomez, the increasing rationalization evident in architectural intentions during the second half of the seventeenth century was only the most conspicuous sign of architecture's adoption of the methods and principles of natural philosophy.[267]

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[263]Hanno Walter Kruft. *A History of Architectural Theory From Vitruvius to Present,* p. 142.

[264] Ibid., p. 152.

[265] Ibid., pp: 142-165.

[266] Ibid., pp: 142-165.

[267] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science*, p.76.

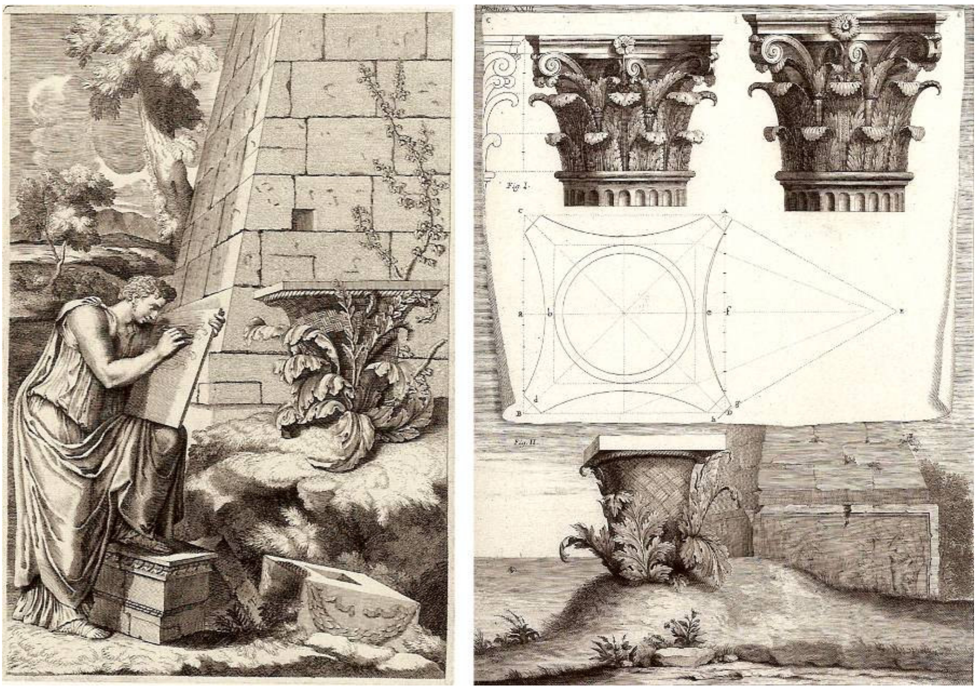

Figure 1.18: (right) Engravings from Fréart de Chambray, (left) Engravings from Claude Perrault. Nature as the source of the Corinthian order. **Source:** Chirostof Thones (ed.) *Architectural Theory: From Renaissance to the Present,* Köln: Taschen, 2003, pp: 246,253.

The works of Guarino Guarini points out the foremost examples of the architectural practice that embraces the assessment of the new geometrical universe: Guarini frankly appropriated the geometrization of the universe set forth by the Galilean revolution and embraced the modern belief in the possibilities of mathematical reason and experimental knowledge.[268] He preferred mathematical reason and empirical observation to ancient authority.[269] In that respect he assigned supremacy to geometry for its power of uniting theoretical and practical knowledge.[270] Depending his geometrical explanation on the intimate relation of

[268] Ibid., p.89.

[269] Janine Debanne. "Surface and Appereance in Guarino Guarini's SS. Sindone Chapel," in Alberto Perez Gomez and Stephen Parcell (Ed.) *Chora, Volume Three: Intervals in the Philosophy of Architecture*, Montreal & Kingston: McGill-Queen's University Press, 1999, P.65.

[270] Ibid., P.50.

figures, Guarini rejected the notion of geometry as an abstract mathematical discipline.[271] Specifically observed in the works of Guarini, was a Baroque obsession to synthesize the specificity of perceived phenomena with a geometrical theory.[272] Explicitly revealed in Guarini's work of *Architecturra Civile,* the architecture of the period was highly concerned with geometrizing the formal practice which takes its form in materializing geometry on stone.[273] As noted by Perez Gomez,

> Guarini's Baroque geometry was not merely a formal science; it was an instrument of rhetoric as well as logic. In correspondence with traditional, Aristotelian perception, geometrical figures assumed the character of symbolic essences, always derived from sensuous intuitions. The geometrization of *res extensa* was the point of departure of modern science and enlightened philosophy, resulted in an increasing exploitation and desecration of nature. During the seventeenth century, however, the geometrical structure of the cosmos guaranteed the achievement of absolute values, establishing an immediate relation between *res cogitans*, *res extensa* and God.[274]

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[271] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science*, p.90.

[272] Martin Jay. "Scopic Regimes of Modernity" in Hal Foster.(Eds.) *Vision and Visuality,* p. 16.

[273] Janine Debanne. "Surface and Appereance in Guarino Guarini's SS. Sindone Chapel", in Alberto Perez Gomez and Stephen Parcell (Ed.) *Chora, Volume Three: Intervals in the Philosophy of Architecture*, p. 50.

[274] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science,* p. 96.

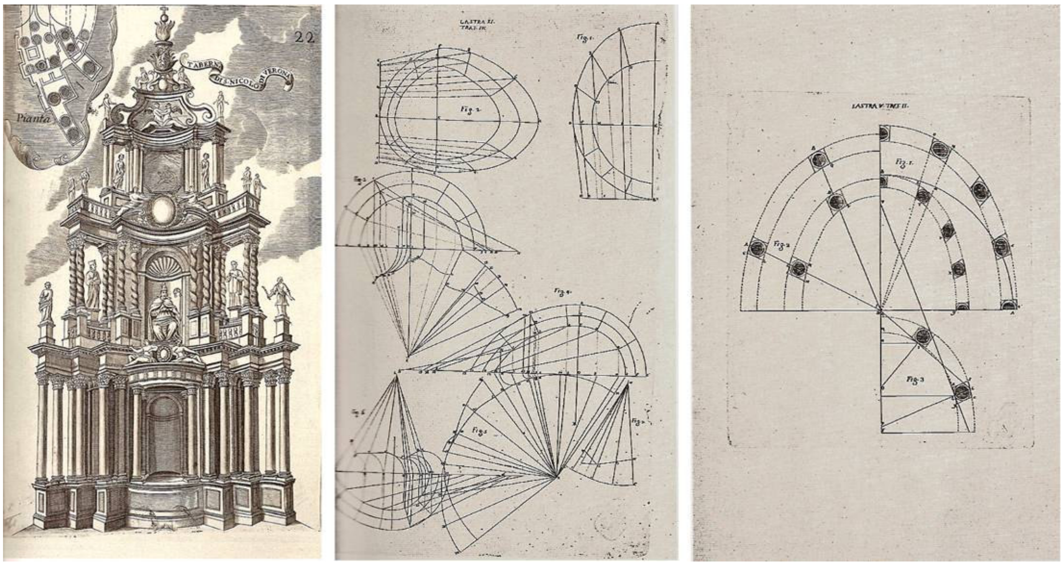

Figure 1.19: Guarini's Baroque geometry. **Source:** Chirostof Thones (ed.) *Architectural Theory: From Renaissance to the Present,* Köln: Taschen, 2003, pp: 131,135.

Geometry in that respect replaced the authority of the ancients as the source of ultimate justifications in architecture.[275] The reason for such a fascination with geometrical explanation to unite the reasonable and the intellectual to the sensuous, the experiential and the empirical, as stated by Perez Gomez, was a general tendency of architecture under the influence of philosophy and science.[276] Baroque architecture as regards became the utmost model of this unification in its fascination with pleating surface qualities and "the tactile presence of a space filled with light and shadow, with angels and mythological figures."[277]

However, this contrasted vividly with the empty and homogeneous spaces of the neoclassical period suggested by Boullée and Ledoux. As claimed by Kaufmann

[275] Ibid., pp: 96-97.

[276] Ibid., p.90.

[277] Ibid., p.97.

in his elaborated work *Architecture at the Age of Reason*, the architecture of the two men reflects the most exemplary forms of modern revolution, that is, the rationalization of form through function. Kaufmann characterizes this revolutionary approach in architecture as the "aim at a different effect on the spectator; the departure from the time-honored, well established patterns; the frantic efforts for the reorganization of the architectural whole and the consequent introduction of new forms."[278]

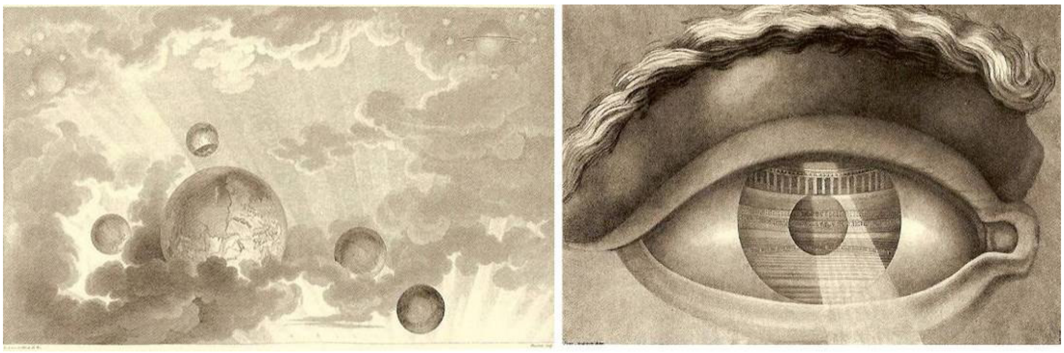

Figure 1.20: (right) Depiction of the cosmos by Boullé, (left) Observation as the source of knowledge (Boullé) **Source:** Anthony Vidler. *Ledoux: Architecture and Social Reform at the End of Ancien Régime*. Cambridge and Massachusetts: The MIT Press, 1990, p. 275.

Towards the end of the eighteenth century, which had seen an increasing rationalization of theory, architects frequently questioned the mythical framework underlying traditional forms.[279] The use of simplified formal elements, a frequent disregard of the classical orders, and the employment of the volumes in the form of simple geometrical bodies became the distinguishing features of the architecture of the French revolution.[280] The tendency toward formal simplicity,

[278] Emil Kaufmann. *Architecture in the Age of Reason: Baroque and Post-Baroque in England, Italy, and France* (1955), New York, 1968, p.142.

[279] Ibid., p.16

[280] Alberto Perez Gomez. *Architecture and the Crisis of Modern Science,* p.130.

evident in French architecture during the second half of the eighteenth century was a result of the increasing domination of reason.[281] From that standpoint, the architecture of Boullée and Ledoux for Perez-Gomez, can be considered as the final embodiment of the neoclassical reconciliation of taste and reason.[282] The search for pure and fundamental forms was unquestionably related to natural philosophy's search for truths of universal validity.[283]

Figure 1.21: A free mason. **Source:** Alexander Roob. *The Hermetic Museum: Alchemy & Mysticism.* Köln: Taschen, 2006, p. 62.

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[281] Ibid., p.130.

[282] Ibid., p.130.

[283] Ibid., p. 131.

Consequently, the methodically gained and accumulated empirical knowledge which successfully undermined the speculative theories of the Aristotelian tradition started to make emphasis on geometry for the unification of mathematical reason and experimental knowledge. In that regard, mathematics and geometry gained a new significance in modern science and philosophy as means of representing physical phenomena or as instruments of deductive explanation and prediction. All these developments in modern science went in hand with the new tendency in architecture towards the systematic explanation of space and its geometrical configuration.

2.4) A Turning Point in Mathematics

2.4.1) The 17th Century Mathematics: From Sensual to Intellectual Faculties

The mathematization of science and the quantification of observational knowledge initiated a new understanding of physical space in seventeenth century. The remarkable change that investigations had preceded in seventeenth century resulted in a new conception of science that differs in methodology from earlier postulates.[284] Trust on the knowledge gained through induction on the basis of observation replaced the general belief of Greek and medieval thought that assumed the existence of basic truths in the human mind.[285] Unlike the earlier investments that appraise mathematical rules and models as the only exact explanation of the physical world, the 17th century studies in science started to make specific emphasis on observational derivations.[286] As regards, knowledge gained through observational analysis became the major source of philosophical thought in which the role of mathematics is now more instrumental than essential.[287]

By the late seventeenth century, mathematics had started to undergo radical changes through which the relation of mathematical concepts with physical space was put into question.[288] Till the sixteenth century, mathematical concepts were accepted as immediate idealizations of or abstractions from experience.[289]

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[284] John Henry. *The Scientific Revolution and the Origins of Modern Science,* p.1.

[285] Morris Kline. *Mathematics: A Cultural Approach*, p. 306.

[286] John Henry. *The Scientific Revolution and the Origins of Modern Science*, p.31.

[287] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 393.

[288] John Henry. *The Scientific Revolution and the Origins of Modern Science*, p.30.

[289] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 393.

However with the appearance of negative, irrational or complex numbers and with the investments on extensive algebra, mathematics has become dominated by concepts derived from the recesses of human minds rather than derivations from the physical world.[290] Mathematicians, as regards, started to contribute concepts rather than abstracting ideas from the physical world.[291] Accordingly, "for the genesis of its ideas mathematics gradually turned from the sensory to the intellectual faculties."[292] As a consequence, mathematics' for a long time accepted foundations have been subjected to an epistemological analysis/questioning.[293] Consequentially, the definitive relation of some mathematical constructs (specifically of the Euclidean system) with physical space started not to be regarded as superior to others.[294]

In that regard, mathematics' formulation of itself around idealizations of observation or abstractions from experience was devaluated on behalf of the new potentials that come with logical possibilities.[295] Mathematics from now on has been detached from its physical context and started to be considered as a logical construct, the validity of which is not a matter of correspondence with physical reality, but an issue of (inner) logical consistency.[296] Consequentially,

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[290] Ibid., p. 393.

[291] Ibid., p.393.

[292] Ibid., p.393.

[293] Bertrand Russell. *An Essay on the Foundations of Geometry,* New York: Dover Publications, 1956, p. ii.

[294] Ibid., p. ii.

[295] Roberto Torretti. *Philosophy of Geometry from Riemann to Poincaré,* Boston: D. Reidel Publishers, 1978, p.61.

[296] Ibid., p.61.

mathematics detached itself from intuition and turned out to be absolute rigor.[297] This new understanding on the nature of mathematics resulted in new "possible geometries" termed as "non-Euclidean".

2.4.2) 19th Century Developments in Mathematics: a Crisis on the Foundations of Mathematics

The new relation between the physical and the mathematical in the nineteenth century triggered the initial questionings on the epistemological reliability of the Euclidian demonstration of physical reality.[298] Specifically focusing on the Euclidean fifth postulate, i.e. "the axiom of parallels", mathematical studies in nineteenth century tried to prove the possibility of other geometries.[299] Hans Reichenbach notes that,

> In particular, the demonstrability of the axiom of the parallels was investigated. This axiom states that through a given point there is *one and only one* parallel to a given straight line (which does not go through the given point), i.e., one straight line which lies in the same plane with the first one and does not intersect it.[300]

Gauss was the first mathematician to doubt explicitly about the Axiom of parallels, and to have conceived the possibility of a non-Euclidean geometry,[301] followed by the "hyperbolic geometry" of Nikolai Ivanovich Lobachevski and Johann Bolyai, and the "elliptic geometry" of the German mathematician

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297 E. T. Bell. *The Development of Mathematics*, p. 282.

298 Hans Reichenbach. *The Philosophy of Space and Time*, p.1.

299 Roberto Torretti. *Philosophy of Geometry from Riemann to Poincaré*, p.40.

300 Hans Reichenbach. *The Philosophy of Space and Time,* p. 3.

301 William Ewald. *A Source Book in the Foundations of Mathematics: From Kant to Hilbert,* Oxford: Clarendon Press, 1999, p.297.

Bernhard Riemann.[302] While, on the one hand in the "hyperbolic geometry" of Lobachevski and Bolyai, it is possible to draw infinitely many parallel lines, on the other hand, in the "elliptic geometry" of Riemann, it is not possible to draw any parallel line. The assumptions of different non-Euclidean approaches, though being mainly counter-intuitive arguments, are accepted to be logically possible within the framework of mathematics.[303]

The questionings of the "axiom of parallels" further necessitated a critical reconsideration of the consistency of the Euclidean *analytico-deductive* formulation of physical space.[304] The Euclidean conception of space accused of being beyond the experiential realm was replaced with further theories of space (Analytic, Differential, Projective, Algebraic, Descriptive or Non-euclidean, Multi-dimensional geometries and topology).[305] Accordingly, new interpretations of the Euclidean parallel axiom brought about different conceptions of space that do not operate on constant zero curvature but rather function with inconstant negative or positive curvatures.[306] As regards, the possibility of inconstant curvatures nullified the assumption that it is possible to move an object from one point to another without any change in quantity and quality.[307] This kind of a possibility is a result of the Euclidean conception of space that is homogeneous and consists of unchanging, certain, absolute elements and relations.[308] Non-

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[302] Roberto Torretti. *Philosophy of Geometry from Riemann to Poincaré,* p.53.

[303] Ibid., p.61.

[304] Hans Reichenbach. *The Philosophy of Space and Time*, p.5.

[305] Ibid., p.5.

[306] Morris Kline. *Mathematical Thought From Ancient to Modern Times*, p. 873.

[307] Bertrand Russell. *An Essay on the Foundations of Geometry,* p.18.

[308] Ibid., p.33.

Euclidean geometries' logical proof of changeable consistency in that regard resulted in a heterogeneous conception of space in which the inner properties of an object are not stable during movement.[309]

In consequence, different manifestations of spatial reality through distinct formulations of geometry triggered critical questionings on the "truth of the factual significance" of Euclidean postulates.[310] Accordingly, the spatial formulation was started to be seen as a consequence of the chosen mode of expression. [311] Rejecting the absoluteness of Euclidean formulation, this kind of an assumption initiated a relativistic comprehension of spatial configuration.[312] Though the possibility of such a relativistic approach to spatial configuration was first noticed by Hermann von Helmholtz, it was mainly elaborated by Henri Poincaré.[313] For Poincaré "experience singles out no specific mathematical geometry: no geometry is true to the exclusion of all others since all geometrical axioms are *conventions*, disguised definitions of a set of primitive predicates.[314]

As regards, the legitimacy of a geometry is accepted to be a result of its proof consistency. [315] In that respect, though appearing artificial when compared with the natural geometry of Euclid, the mathematical legitimacy of other geometries was accepted to be beyond question.[316] As observed by Hans Reichenbach, what

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[309] Ibid., p.33.

[310] Roberto Torretti. *Philosophy of Geometry from Riemann to Poincaré,* p.169.

[311] Ibid., p.169.

[312] Ibid., p.169.

[313] Ibid., p.169.

[314] Elie Zahar. *Poincaré's Philosophy: from Conventionalism to Phenomenology,* p.70.

[315] Hans Reichenbach. *The Philosophy of Space and Time*, p.5.

[316] Ibid., p.5.

was intended by nineteenth century mathematicians was to stress the fact that the essence of a geometrical proof is contained in the logic of its derivations, not in its correspondence to the physical.[317] Leading to a distinction between the physical and the mathematical, Reichenbach asserts that;

> …the discovery of non-euclidean geometry has a fundamental significance: it divides the problem of space into two parts; the problem of mathematical space is recognized as different from the problem of physical space…Up to that time physics had assumed the axioms of geometry as the self-evident basis of its description of nature.[318]

As regards, the discovery of non-Euclidean geometries gave rise to a duality between *physical* and *possible* mathematical spaces: "Mathematics reveals the possible spaces; physics decides which among them corresponds to physical space."[319] Consequentially, in contrast to all earlier conceptions that assumed a correspondence between the physical and the mathematical reality, in nineteenth century, the reality of the physical and the mathematical is started to be conceived as independent from each other."[320] Mathematics, rather than being the ultimate truth of the physical, turned out to be an instrument for its investigation.

In consequence, it can be asserted that developments in nineteenth century mathematics and the possibility of different geometries have significance for epistemological arguments and in specific for discussions on the foundation of mathematics. As regards, the achievements of non-Euclidean geometries are not an invalidation of the Euclidean conception and systematization of space, but rather, the logical possibility of other geometries is both a reconsideration of the

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317 Ibid., p.4.

318 Ibid., p. 6.

319 Ibid., p. 6.

320 Ibid., p. 6.

epistemological absolutism of Euclid and the identicality of physical and mathematical concepts.

Though all these developments in mathematics were not utilized in nineteenth century architecture, they became the major of source of architectural practice and theory in the digital period. As regards, the next chapter will critically focus on the changing conception of architectural production in the digital period with respect to the shifting relation of mathematics to architecture.

CHAPTER 3

TOWARDS AN INSTRUMENTAL USE OF MATHEMATICS

3.1) Interdisciplinarity

3.1.1) A new Platform of Exchange and Cross-fertilization for Architecture

Architecture's recent engagement with digital technologies brought forth various questionings either related with their use as representational tools or as form generative media.[321] Being more than a practical utility, the precision and accurateness that come up with the incursion of these technologies, are accepted to result in drastic changes in the conception of the architectural process.[322] Moreover, the extended possibilities of visualization, the surmounted limitations of construction and the overwhelmed restrictions of representation achieved through digital technologies are seen to require not only a new understanding of design practice but also a new conception of architectural theory –distinct from any previous assessment.[323] The reason for such a requirement is claimed to be mainly a result of the new proposed technique, methodology and logic of such digital technologies that come with the numeric control of the architectural process.

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[321] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*. London and New York: Spon Press, 2003, p. 13.

[322] Ibid.

[323] Ibid.

The numeric control that lies behind the creation, development or realization of any architectural product in the digital process is seen to force not only the formal vocabulary of an architectural heritage but also any acknowledged principle or norm in the conception of design process.[324] As regards in the course of digital production, the historically loaded principles of architecture[325] that are accused of being static, deterministic and normative[326] are put into erasure for the sake of new possibilities that come with architecture's interaction with other disciplines.[327] Architecture in that regard entered a new self-definition procedure in which the re-definition or transformation of many architectural concepts are not only done with respect to the disciplinary frames, but rather include non-disciplinary references.

This new definition of architectural production termed as "folding"[328] by Greg Lynn appraised any form of relation or engagement with different fields, while promoting "a more fluid logic of connectivity".[329] The efficacious consequence of conceiving architecture as a practice of folding Lynn states, resulted in "a new

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[324] Greg Lynn. *Animate Form.* New York: Princeton Architectural Press, 1999.

[325] Peter Eisenman. "The Diagram and the Becoming Unmotivated of the Sign," *Diagram Diaries.* New York: Universe Publishing, 1999, p. 211.

[326] Greg Lynn. *Animate Form,* p. 9.

[327] Ibid., p. 9.

[328] The term "folding" is mainly used with reference to Deleuze's work: "*The Fold: Leibniz and the Baroque"* in which Deleuze proposes a new comprehension on the theory of knowledge with a metaphoric reference to Baroque architecture. Specifically opposing to Cartesian epistemology and its abstraction/reduction of reality to an absolute image produced by mind, he develops a pluralistic approach in achieving knowledge with a particular reference to the works of Leibniz. Gilles Deleuze. *The Fold: Leibniz and the Baroque,* Trans. Tom Conley, Minneapolis and London: University of Minnesota Press, 1993.

[329] Michael Speaks. "Folding Toward a New Architecture" in, Bernard Cache. *Earth Moves: The Furnishing of Territories*. Trans: Anne Boyman. Cambridge, Massachusetts: The MIT Press, 1995, p. XIII. Originally in; Greg Lynn (ed.) *Folding in Architecture*, London: Architectural Design, 1993.

ability to integrate unrelated elements within a new continuous mixture."[330] Therefore under the influence of the new "logic of fluidity" or with the inspiration of the methodology of "folding", the practicing architects of the digital period started to benefit from extra-disciplinary concepts, achievements and developments.

In the course of this "folding" process, abstract diagrams from different fields through "formal transformation", "wrapping" or "morphing strategies", are juxtaposed or merged with particular geometric patterns in order to obtain the final architectural form.[331] Accordingly, the architectural form is started to be conceived as an outcome of "generative *deformation*" strategy,[332] rather than an intentional formation process.

> Borrowing from Deleuze, DeFormation refers to these tentative formal links with contingent influences as affiliations, and engendering affiliations is the foremost mechanism of by which DeFormation attempts to point. Affiliations are distinct from traditional site relations in that they are not *pre-determined relationships* that are built into the design, but *effects* that flow from the intrinsic formal, topological or spatial character of the design. [333]

Consequentially, this undeniable change in the process of architectural production resulted in a shift in the conception of formal creation: the architectural form

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[330] Ibid., p. XIII.

[331] Jeffrey Kipnis. "Towards a New Architecture," in Giuseppa Di Cristina (ed.) *Architecture and Science*. London: Willey-Academy, 2001, p. 23. With reference to René Thom's and Lacan's theory of catastrophe, Kipnis outlines "fold" as "a map of an event, a geometric description of the unexpected, a *diagram of the virtual.*" He further states that though the original definition of the term rejects any representational implication for to generate different fields of organization; architecture's utilization of the concept are mostly done through representational methods that include visual juxtaposition or merging of some graphic layers of architecture (i.e. visual layering of conceptual and site analysis or functional schemes) and different out-disciplinary sources.

[332] Brian Massumi. "Sensing the Virtual, Building the Insensible," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 198.

[333] Ibid., p. 198. (Italics are mine.)

rather than being the unique result of architect's ideation, imagination or intention, is started to be conceived as a reactionary/responsive solution to the external *effects*. And by means of these external *effects* the appreciated blending or cross-fertilization of different discipline sources is claimed to have been achieved, in most cases either visually (formally) or conceptually.[334]

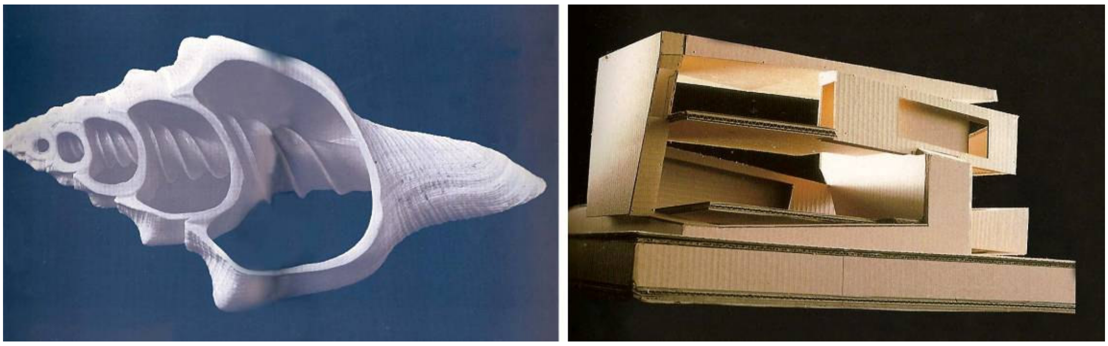

Figure 2.1: New sources of formal creation. **Source:** Ben van Berkel and Caroline Bos. *Technique: Network Spin*. Amsterdam: UN Studio and Goose Press, 1999.

However within this cross-fertilization program with different disciplines, though the aim is set to develop a new conception of architecture that well fits to the requirements of information era through the possibilities of data exchanges, underestimation or rejection of any prior systematic organization of codes[335]

[334] Greg Lynn. "Architectural Curvilinearity: The folded, The Pliant and The Supple," in Giuseppa Di Cristina (ed.) *Architecture and Science*. London: Willey-Academy, 2001, p. 27. Eisenman's recent works can be asserted as the examples of visual blending in which visual sources from evolutionary biology in specific René Thom's Catastrophe theory and architecture are integrated via a visual layering methodology. And the re-readings of philosophical, mathematical or scientific concept within architectural discourse exemplify the mentioned smoothing methodology of concepts, in the course of which out-disciplinary concepts loose their identity for the benefit of productivity and novelty.

[335] Diane Agrest. "Design versus Non Design" in *Oppositions Reader: Selected Readings from A Journal for Ideas and Criticism in Architecture 1973-1984,* Ed. K. Michael Hays, New York: Princeton Architectural Press, 1998, p. 335. Diane Agrest claims that the articulation or exchange between architecture and other systems and disciplines requires a thorough analysis of the

opened the way for circumstantial relations and occasional operations. In that regard, the strict definition of borrowed concepts are exposed to a constant transformation that vary in response to changing needs and aesthetic preferences or even individual interpretations. Ultimately, this interdisciplinary condition erasing any boundary line of the architectural discipline itself, formed a new exchange platform in which concepts, metaphors or images from a wide range of fields such as mathematics, physics, molecular biology, topology, fractals, chaos theory, DNA sequencing became the main references.[336] Disparate formal, programmatic and structural elements taken from these fields or disciplines are started to be re-integrated within the "neutral space of digital technologies"[337] by means of "visual layering" or "morphing techniques, tactics, strategies or methodologies."[338] Henceforth, architects started to benefit from new combinatorial models[339] in order to achieve diversity, productivity and novelty in final form, rather than to endeavor within strict disciplinary definitions. As regards, models exported from different disciplines and fields through visual or conceptual translation/transformation turn out to be the most productive references of formal/architectural production.

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differences and similarities through the clarification of the codes according to their relation to design and referenced/utilized sources.

336 Antoine Picon. "Architecture, Science, Technology, and the Virtual Realm," *Architecture and The Sciences: Exchanging Metaphors,* Antoine Picon and Alessandre Ponte (eds.), Princeton: Princeton Architectural Press, 2003, p. 292.

337 Alicia Imperiale. *New Flatness: Surface Tension in Digital Architecture,* Berlin: Birkhäuser, 2000, p.38, 79.

338 Jeffrey Kipnis. "Towards a New Architecture," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p.19.

339 Ben van Berkel and Caroline Bos. *Imagination: Liquid Politic*. Amsterdam: UN Studio and Goose Press, 1999, p. 21.

However within this fruitful condition, as observed by Michael Hays, architecture's derivation of its material from "vividly distant disciplines" became almost random, -turning out to be an "*ad hoc* constellation" that built its very reality on the heterogeneity of interpretations and interconnections.[340]

> The necessary and correct interpretation of different discourses was radicalized in the fruitful but problematic concept of intertextuality. And henceforth architecture theory would draw its material from the most wildly distant disciplines and its intertextual references would become almost random –an ad hoc constellation that necessarily commented on other texts inside and outside architecture, that depended on a heterogeneous body of texts that would be glossed, interconnected and rewritten. Attempts were made to match a certain reading of this text with a reading that building and architecture theory became radically occasional.[341]

Accordingly, Hays further notes that within this intertextual condition so many concepts taken from different disciplines or philosophies through an interdisciplinary import is started to be transformed into practical strategies for producing architecture.[342] Following the theory of "assemblage"[343] introduced by Gilles Deleuze and Felix Guattari in their book *A Thousand Plateaus*, the practitioners of the contemporary architecture started to make emphasis on the collection of heterogeneous components from different realms/fields while rejecting any homogenizing totality that the discipline of architecture proposed.[344]

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[340] K. Michael Hays. "Architecture Theory, Media, and the Question of Audience" *Assemblage,* No. 27, Tulane Papers: The Politics of Contemporary Architectural Discourse, August, 1995, p. 43. Hays notes that different from previous engagements with diverse disciplines or study fields, contemporary architecture's recent affiliation with extra-disciplinary concepts or theories does not require any prior structural similarity or transcoding mechanism. He further states, that the appreciated subjective selection of any term and image as an operational ground is the specific departure of recent practice.

[341] Ibid., p. 43.

[342] Ibid., p. 43.

[343] Ibid., p. 42.

[344] Gilles Deleuze and Felix Guattari. *A Thousand Plateaus: Capitalism and Schizophrenia*, Trans: Brian Massumi. Minneapolis: University of Minnesota Press, 1993, pp: 327-328. The theory of

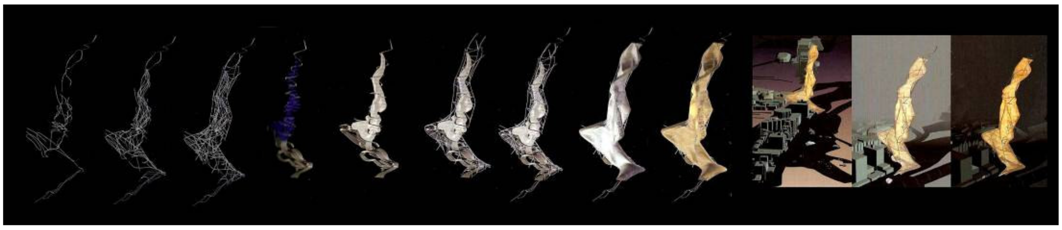

Figure 2.2: The evolution of form. **Source:** Peter Zellner, *Hybrid Space : New Forms in Digital Architecture*, New York: Rizzoli, 1999, pp: 114,115.

Therefore, "a smooth ideology" as termed by Hays,[345] took the place of dialectically opposed strategies which could be categorized either as conflict and contradiction or unity and reconstruction/composition.[346] Smooth translation/transformation of diverse fields to practical strategies in architectural production under the numeric control and guidance of digital technologies as claimed by Lynn is assumed to enable architects an intensive integration of differences within continuous yet heterogeneous systems.[347] This new method of

assemblage can be explained with respect to Deleuze's more general conception or understanding of events. As stated by John Rachman, for Deleuze, "events never happen out of a tabula-rasa, but come out of complications, out of the fold; and time occupies a "complicated" rather than a linear or circular space: it lies at the intersection of multiple lines that can never be disentangled in a single transparent plane given to a fixed external eye." (John Rajchman. "Out of the Fold," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 36.) Therefore the determinant role of any fixed subject (the architect in the case of architecture), any static, linear theorization or authority of concepts (changing specifications of principles, norms and values such as utility, firmness, beauty, unity, harmony etc. in architecture) are claimed to be mere reductionism. Thus for, instead of assuming architecture as a homogeneous totality in which (predefined) concepts can be applicable to any design for to produce the same effect, it is claimed that contemporary architects started to search for heterogeneous, occasional determining factors that result in particular solutions.

345 K. Michael Hays. "Architecture Theory, Media, and the Question of Audience" *Assemblage,* p. 43; and Jeffrey Kipnis. "Towards a New Architecture," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p. 18. This shift in ideology is mostly identified with the shift in philosophy from Derridean to Deleuzian discourse.

346 Greg Lynn. "Architectural Curvilinearity: The folded, The Pliant and The Supple," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p. 26.

347 Ibid., p. 26.

translation/transformation in that regard, while maintaining the integrity of disparate elements, is claimed to preserve differences and diversities through "fluid tactics of mixing and blending."[348] Thereafter, disciplinary concepts and methods of architecture accused of being "rigid", "static" and "closed" are replaced with more "flexible strategies".[349] The production of the architectural object as a result became to be dependent on external forces, effects, concepts and methodologies. As regards, architectural practice detached from any hierarchical organization of process is acknowledged to invalidate the vertical structures of formal production. Prior development and formation of design ideas or guiding mechanism of theories are devaluated on behalf of the in-determinant, arbitrary and productive results of horizontal relations.[350] Henceforth the concepts of "form," "function," "order," "composition," "proportion," "beauty" or even "design" and "theory" –being hierarchical structures, are put into dissolve within unconscious, arbitrary, non-totalizing, smooth systems of "emergence" and "becoming".[351] In that respect, the next sub-chapter will focus on the effects of these changes with reference to the shifts that they propose in the conception of architectural intention and production.

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[348] Ibid., p. 26.

[349] Ibid., p. 26.

[350] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*, p. 13.

[351] Ibid., p. 13.

3.2) Privileged Role of Abstract Information over Material Reality

3.2.1) Uniformity between Architect's Ideation/Intention and Numerically Controlled Architectural Production

Within the interdisciplinary context and through the changing conception and definition of architectural production, discussions on the role of the architect's intention in the architectural process gain a new acceleration. It can be asserted that these discussions mainly terminate around the shifting conception of architectural production that departs from a priori definitions that see aesthetic qualities or functional requirements as the basic references/grounds of the architect's intention. As regards, unlike any historical account that proposes a vertical relation between particular architectural principle/norm/ground and the object, the contemporary architectural production promoted by digital technologies is accepted to offer a novel conception of the design process.

Disregarding any hierarchical design approach, the production of the architectural edifice in numerically controlled architectural production is supposed to "enforce the potentials of mediation and expand the limits of imagination", going beyond the possibilities of small technologies.[352] Accordingly, developments in digital technologies, being more than a practical utility, started to threaten the once celebrated role of human reasoning which was assumed to be the sole connection between the architectural object and the architect's ideation. In that regard, the architect's intentionality in architectural production is put into question on behalf of the extended possibilities of digitally driven formal process. Brian Massumi notes that,

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[352] Ben van Berkel and Caroline Bos. *Techniques: Network Spin*, Amsterdam: UN Studio and Goose Press, 1999, p. 167.

> One thing swept away is the popular image of the architect as autonomous creative agent drawing forms from an abstract space of Platonic pre-existence to which he or she has inspired access, and artfully dropping them into the concrete of everyday existence, which is thereby elevated. The architect's activity becomes altogether less heroic…The architect becomes a prospector of formative continuity, a tracker in an elusive field of generative deformation.[353]

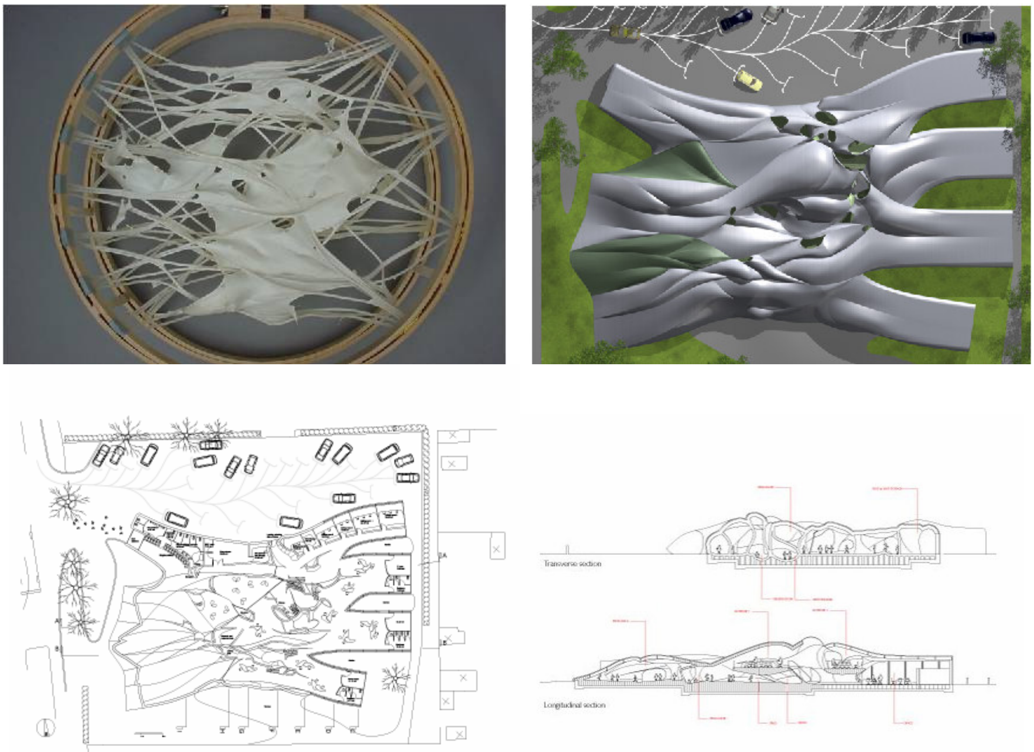

Figure 2.3: Nox, soft office.
Source : http://www.noxarch.com/flash_content/flash_content.html, last accessed in 05.12.07.

As noted by Brian Massumi, developments in digital technologies providing explorative and experimental investigations is accepted to cause a shift in the conception of the architect's role in architectural production, while displacing its

[353] Brian Massumi. "Sensing the Virtual, Building the Insensible," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 198.

classical notions.[354] Jameson states that the classical traditions of rhetoric, eloquence and even of handicraft was inclined to celebrate the human achievement and to welcome continuities between the intention of the artist and the work itself which was seen as the mark of the architect's elevated intentionality.[355] Yet for the romantic period he declares, the architect's intention was assumed to be a sign of interiority which was an interface between nature and the final product.[356] The result was the appraised status of the architect for being a mediator or even a "genius" in the translation of the unconscious formation of the nature to a conscious achievement in his production or creation. [357]

Jameson continues to note however that architecture's recent engagement with digital technologies is accepted to require a new conception of architectural intentionality as the products of the contemporary period became the mark of the resolved causality between the architect's objectives on the object.[358] It is even seen as a breakdown from human reasoning and instead as a preference for the *self organizing structures of nature* as the ultimate ground/reference of architectural production.[359] In that respect, the well-regarded independency of form from the personality of the architect, from aesthetic conventions or functional requirements is supposed to lead to a "neutral business of architecture that emanates out of the underlying data" derived from an external source.[360] The

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[354] Ibid., p.198.

[355] Fredric Jameson. "Aronoff and Ideology," in Peter Eisenman. *Blurred Zones: Investigations of the Interstitial*, New York: The Monacelli Press, 2003, p. 62.

[356] Ibid., p. 62.

[357] Ibid., p. 62.

[358] Ibid., p.62.

[359] Michael Hensel. "Finding Exotic Form: An evolution of Form Finding as a Design Method," in Emergence: Morphogenetic Design Strategies. (ed. Helen Castle) *Architectural Design*, p.27.

[360] Ben van Berkel and Caroline Bos. *Techniques: Network Spin*, p. 165.

appreciation of form as the ultimate result of external data as stated by Ben van Berkel and Caroline Bos is claimed to be a definitive shift from the economic strategies of formal creation to multiplied and diversified possibilities of digital production.[361] Van Berkel and Bos state that;

> If any form is possible and all are equally functional in an economic sense, the pragmatic, standardized language of Modernism has lost its imperative. A simple self evident reasoning no longer justifies any specific form… New models of organization are developed in order to proportion and structure digital information. Parameters are formulated, once again expressing architectural values in rational functional and objective terms…As the evolution of the chosen parameters is traced over time, the project emerges as if of its own accord…The techniques are used as a direct and transparent medium to uncover the neutral values forming the basis of the project.[362]

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[361] Ibid., p. 165.

[362] Ibid., p. 165.

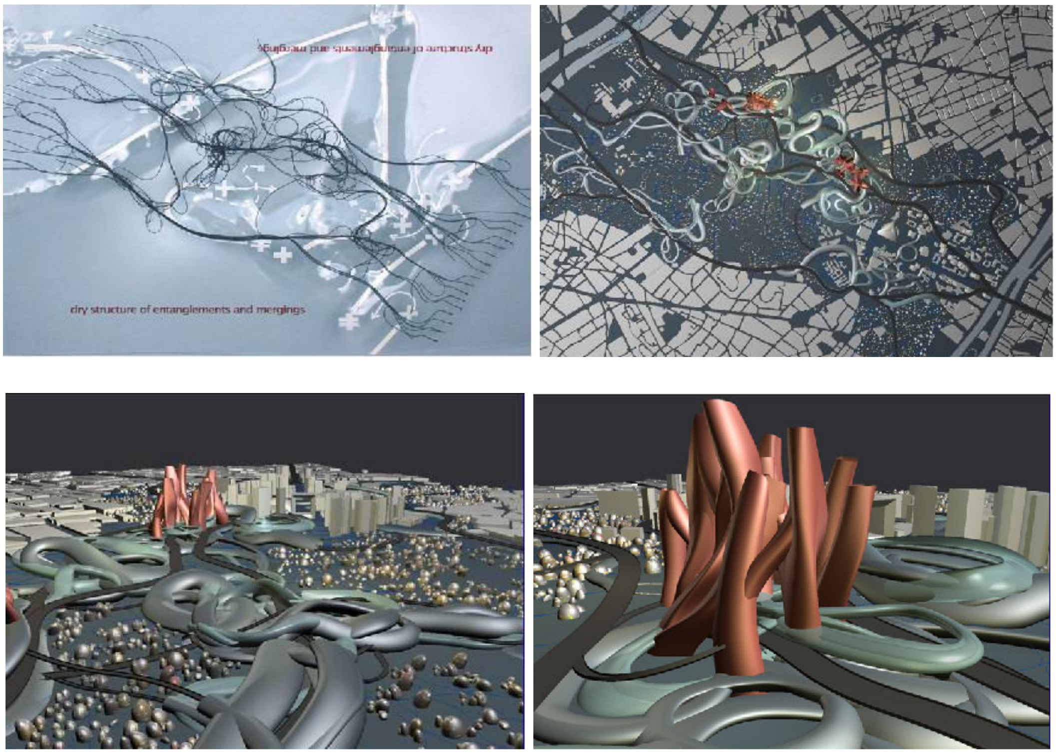

Figure 2.4: Parisbrain (Paris, France) by Nox, an experimental approach to form generation**, Source:** Marie Ange Brayer, Frederic Migayru, Nanjo Fumio (eds.) *ArchiLab's Earth Buildings: Radical Experiments in the Architecture of the Land,* New York: Thames and Hudson, 2003.

In digital production, the data derived from a particular immediate reality of present is therefore not only accepted as the only source of final form, but also seen as the basic requirement of a transparent, objective and rational process.[363] The reality in this process standing on its own is supposed to be the neutral ground of architecture whose transformation into architectural language/form/ object is assumed to provide an "a-signifying", "unbiased" and "open" system.[364] Accordingly, the image of the architectural object is claimed to be an expression of the (information/data) content rather than a sign of a disciplinary language,

[363] R. E. Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture" in Peter Eisenman. *Diagram Diaries,* New York: Universe Publishing, 1999, pp: 15-21.

[364] Ibid., pp: 15-21.

norm or principle.[365] The very validity of the architectural product as regards is started to be conceived as resulting from the direct, confirmed relationship between the final architectural form and the utilized data, rather than established relations to architectural principles, orders or norms and grounds (i.e. the ruling/guiding structures of the architecture which are historically defined or accepted as the ultimate grounds of architectural production).

3.2.2) Surmounting the Limits of Human Reason and Intention

The creation of form in contemporary architectural production is assumed to be no longer a property of the architect's intention.[366] Therefore, the conscious achievements of the architect accused of being "determinant" and "deficient" are replaced with a new methodology of "tactical bridging of different fields that stand in relation to each other as mutual outsides."[367] Accordingly, the achievements of the new digitally driven formal production are appraised as new design solutions for the tactic management of time based material processes, scales and milieus rather than a provision of singular and finite design solutions.[368] Destabilizing the pure authority of the author/architect on the object, the generation of the materialized form is accepted to be determined by data derived from external sources or fields.[369] Since the compatibility/convenience of

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[365] Ibid., pp: 15-21.

[366] Brian Massumi. "Interface and Active Space" published in the *Proceedings of the Sixth International Symposium on Electronic Art, (Montreal, 1995)*, p. 6.

[367] Ibid., p. 6.

[368] Michael Hensel. "Finding Exotic Form: An evolution of Form Finding as a Design Method," in Techniques and Technologies in Morphogenetic Design. (ed. Helen Castle) *Architectural* Design, Vol. 74 No. 3, 2004, p. 33.

[369] Bernard Cache. "Topological Architecture and The Ambiguous Sign," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 128-129.

the out-disciplinary models is bound to neither the affirmations of the architect nor the verifications of the disciplinary conventions; either visual or conceptual similarities, analogies or fabrications with out-disciplinary sources take the once confirmed role of the architect in decision making for all steps of architectural production.[370]

Figure 2.5: Nox_center pompidou II.
Source : http://www.noxarch.com/flash_content/flash_content.html, last accessed in 05.12.07.

As regards, this new type of formal production notwithstanding on the reason or intent of the architect, is taken for granted as to be shaped by the integration of "dynamic forces", "velocities", and "directions".[371] Termed as "emergence," this new formation/conception of architectural production is assumed to bring about new stances that are not grounded on human reason or intention.[372] Instead of developing a unique idea from its initial state to construction this new conception of architectural production is accepted to operate through a new design

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[370] Ibid., p. 128-129.

[371] Ben van Berkel and Caroline Bos. *Effects: Radiant Synthetic*, Amsterdam: UN Studio and Goose Press, 1999, p. 25.

[372] Ibid., p. 25.

methodology of finding a form. Therefore, a contemporary appreciation of "form finding" that deploys and instrumentalizes *the self-organization of material systems* under the influence of extrinsic forces[373] replaced the traditional understanding of "form making." In that respect, the evolutionary form generation software that incorporate through an "environment specific random factor" as well as "genome mutation", (which are supposed to be the sources of contingent influence,) became the most essential tools of architecture in formal creation.[374] As a result, "morpho-ecologies", "habitat-site systems", "genetic algorithms" and "evolutionary structures" (which can be generally termed as self organizing material systems) rather than the compositional principles, turn out to be the basic references of architects in contemporary architectural production.[375]

Greg Lynn notes that within this new conception of architectural production, the creation of form is started to be conceived as a process of evolution rather than a gathering of different shapes and volumes according to absolute, unchanging rules.[376] In that regard, architecture's engagement with different models of self-organizing systems is supposed to present new challenges for the advancement of formal production.[377] Grounding on the Deleuzian concept of "vicissitudes" which can be defined as the "incorporation of unpredictable events through intensities", Lynn states that it is difficult to localize or identify the occurrences, as any logic of vicissitude he claims is dependent on both "the intrication of local intensities"

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[373] Michael Hensel. "Finding Exotic Form: An evolution of Form Finding as a Design Method," Weinstock, Michael. "Morphogenesis and the Mathematics of Emergence," in Emergence: Morphogenetic Design Strategies. (ed. Helen Castle) *Architectural Design*, pp: 10-33.

[374] Ibid., p.31.

[375] Helen Castle (ed.). Techniques and Technologies in Morphogenetic Design, *Architectural* Design, Vol. 74 No. 3, 2004.

[376] Greg Lynn. *Animate Form,* p. 9.

[377] Ibid., p. 9.

and "the exegetic pressure exerted on those elements by external contingencies."[378] He further adds that "neither the intrications nor the forces which put them into relation are predictable from within any single system; connections by vicissitude develop *architectural* identity through the exploitation of local adjacencies and their affiliation with external forces."[379] The organizational models transformed into practical strategies in architecture, henceforth, shifted the long ongoing emphasis in formal creation from the object or the architect to the particular external forces and their relations. [380]

The need for complex models of organization so as to understand the inner dynamics of architectural production is shaped around the claim that reality is too complex to be grasped by the architect alone.[381] Therefore, the development of new models of reality that operates through numeric control and the resultant capacity for calculating material procedures is supposed to offer a shift in the conception of the architect's role from the master of a hierarchical, categorical and vertical activity to an organizer of an information gathering process.[382] Accordingly, it is claimed that "the architect is no longer the unique author, the sole master of the form"[383] but rather he is accepted as an operator among many.

Within this new model of architectural production as asserted by R. E. Somol, what is transformed, organized, or channeled by the architect is not limited to

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[378] Greg Lynn. "Architectural Curvilinearity: The folded, The Pliant and The Supple," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p. 27.

[379] Ibid., p. 27. (Italics are mine.)

[380] Ben van Berkel and Caroline Bos. *Techniques: Network Spin,* p. 160-161.

[381] Hans Haacke. *MVRDV at VPRO.* Barcelona: Actar, 1999, p. 10.

[382] Ibid., p. 10.

[383] Ibid., p. 10.

vertical structures but more significantly horizontal and nonspecific "forces" -i.e. economic, political, cultural, local and global effects, are also included in the formation of the architectural edifice.[384] This transformational method therefore authorizing the translation of external forces to internal, disciplinary practical tools is claimed to serve to dislocate any static contemplation of the high-art object.[385] Since the contemporary architectural tendency is asserted to concern with revealing the syntactic relations of architectural language, present studies in formal production became the mark of the move from "the perceptual aesthetic qualities of the object toward an attempt to mark the conceptual relationships that underlie and make possible any (and every) particular formal arrangement."[386]

3.2.3) Mathematical Relations as the Necessary Provision of a Digitally Uniformed Process

As the formation of an architectural edifice in a digitally driven process is seen to be a direct outcome of the active external forces/data, the process of architectural production has become to be conceived as a *controlled experiment*. Therefore it is accepted that the choice of ingredients –that is the forces, analogical structures, or organizational models from different sources, have a vital role for the outcome. As regards, it is claimed that the final product, rather than being a passive result of a closed individual process taking form under self- organizing systems is declared to involve greater openness with reference to the end product than any other technique.[387] The appraised openness of architecture as asserted by Ben van

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[384] R. E. Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture" in Peter Eisenman. *Diagram Diaries,* p. 24.

[385] Ibid., p. 16.

[386] Ibid., p. 15.

[387] Ben van Berkel and Caroline Bos. *Techniques: Network Spin*, p. 166.

Berkel and Caroline Bos is a genuine result of the new digitally driven modeling methodology which makes possible architects to inject any change in the organization of patterns that take place during the process, enabling a complete acknowledgement of complexity.[388] Consequentially rather than a static, linear model of architectural process that does not permit change; a dynamic model of production is supposed to be applied.[389]

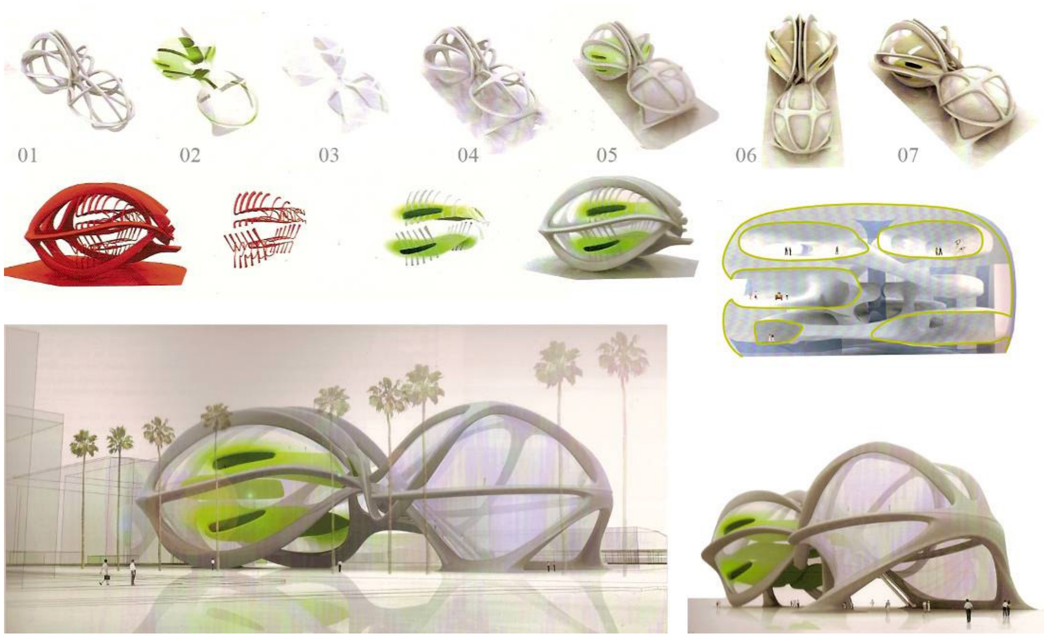

Figure 2.6: The Exotic Collection by Davis Campos, The design of a small museum. **Source:** Yu-Tung Liu (ed). *Demonstrating Digital Architecture*, Boston: Birkhäuser, 2005, pp: 153-155.

It is assumed that the digitally driven process offers architecture a new design logic by means of which complex reality is broken down into simple, quantifiable

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388 Ibid., p. 166.

389 Ibid., p. 166.

data which can be readily re-elaborated into buildable matter.[390] Consequentially, the architectural process is declared not to be rooted in "voluntary modern abstraction", but in numerically controlled "binary abstraction of reality."[391] Therefore digitally driven possibilities are supposed to offer a move "from ambiguity to undecidability or from binary oppositions to micro-multiplicities."[392] Rather than a search for a unity in architectural production or a unified theory that insists/grounds on priory meaning and signification, this new process is accepted to appraise an endless chain of conjunctions.[393] In this numerically controlled and guided process of architectural production, all technical, functional or aesthetic terms are disregarded in the definition of the architectural edifice.[394] The objects created, "informe" as termed by Peter Eisenman, are started to be seen as "just things" which are the concretized forms of information.[395]

> Perhaps, then, we have here a rather extraordinary condition in which a mutant form of reification continues its work of flattening out disciplinary techniques, de-differentiating across previously distinct practices, erasing the specific traces of production and homogenizing particular experiences into one generic experimental flow and yet at the same time does not eradicate the architectural impulse but rather is paradoxically pressed into service of altogether new ones more adequate (just maybe) for our present.[396]

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[390] Hans Haacke. *MVRDV at VPRO*, p. 18.

[391] Ibid., p. 18.

[392] R. E. Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture" in Peter Eisenman. *Diagram Diaries,* p. 18-19.

[393] Ibid., p. 18-19.

[394] Ibid., p. 18-19.

[395] Ibid., p. 18-19.

[396] K. Michael Hays. "Prolegomenon for a Study Linking the Advanced Architecture of the Present to That of the 1970s through Ideologies of Media, the Experience of Cities in Transition, and the Ongoing Effects of Reification" *Perspecta,* Vol. 32, Resurfacing Modernism, 2001, p. 106.

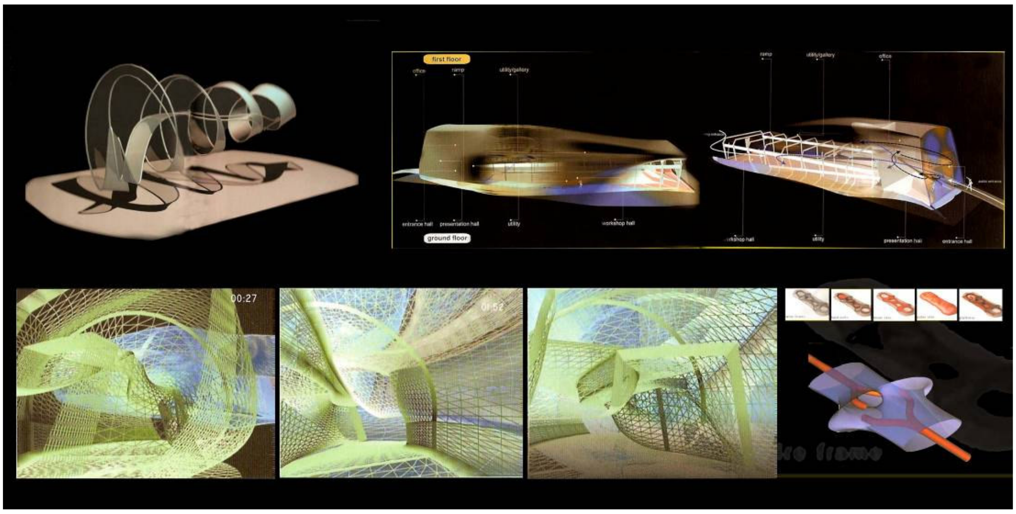

Figure 2.7: The architectural form taking shape through information management. **Source:** Ben van Berkel and Caroline Bos. *Technique: Network Spin*, Amsterdam: UN Studio and Goose Press, 1999.

As regards, Lynn claims that the architectural form is detached from the context of "autonomous purity" to become an answer to "contextual specificity."[397] The whole process of architecture is then summarized as the invention of new methods and techniques to cope with this reality. Accordingly, the handling of information became to have a direct connection with architectural form. Therefore, the architectural form, instead of depending on the subjectivity of a given author, is regarded to rest on the handling of information about reality.[398] In that regard, Jaime Salazar claims that "a part of the "unexpressible" aspect of architecture has come down on the side of its statistical treatment."[399] In view of these changes, the next chapter will focus on the shifts in the architectural process that come up with the use of self- organizing models and generative systems.

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397 Greg Lynn. *Animate Form,* p.11.

398 Jaime Salazar. (Ed.) *MVRDV at VPRO*, p. 3.

399 Ibid., p. 3.

3.3) The Architectural Production as Intellectual Activity

3.3.1) Self Organizing Systems: Extending the Limits of Formal or Functional Approaches in the Design Process

Accusing traditional methods of architecture for being vertical, hierarchical and linear, as asserted by Greg Lynn the promotion of temporal techniques is started to be made through discussions that emphasize the inadequacy, inconveniency or even incompetence of such conventional techniques and conceptions.[400] The comparison of two periods (i.e. traditional and digital) demarcated through technological developments, henceforth turns out to be the unique source of reference for displaying the extended possibilities of digitally driven processes. As claimed by Ali Rahim,

> Architects who use analytical methods typically work from top down: they formulate an overall design concept and then refine the design at successively more detailed levels. Designers who use temporal techniques begin, instead, with the individual parts of a system, linking these elements together to form larger components until a complete assemblage emerges…The emphasis shifts, however, from trying to analyze or represent that which is already known –the preconceived design concept- to discovering relationships and techniques that are yet unknown and that may emerge through feedback.[401]

In that regard, it can be asserted that the generative role of digital techniques is accepted to be a consequence of the architects' simultaneous interpretation and manipulation of a computational structure in which possibilities of extended visualization technologies actively shape the designers' thinking process.[402] The

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[400] Greg Lynn. *Animate Form.*

[401] Ali Rahim. *Catalytic Formations: Architecture and Digital Design*, London and New York: Taylor & Francis, 2006, p.25.

[402] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*. London and New York: Spon Press, 2003, p. 27.

architectural form, rather than being the "projected idea of the architect", starts then to be conceived as results of the reactions to a context of external "forces" or actions.[403] These forces or actions are supposed to create "fields of indetermination" from which unexpected and genuinely new forms might emerge.[404] Therefore, Branko Kolarevic argues that un-predictable variations are generated from a variety of forces and actions that are external to the architecture.[405] These forces and actions gathered from the architectural program, site or the out-disciplinary external references[406] with the aid of computer programs and put into interaction in the course of a mathematical and numeric layout are seen to be the new challenges on the way to indeterminate and self-governing generative architectural processes.

Stan Allen asserts that in consequence of conceiving architectural production as a self-governing generative program that operates through the data collected in the course of a particular project, the architectural object uncovered/stripped from the preferences and subjective interpretations of the architect, turns out to an objective response to the necessities and facts of the process.[407] In that regard, the architectural object rather than being the "projection" and "*signifier*" of the architect's ideation, imagination and "*ingenuity*", through mathematical and geometric relations is started to be conceived as an operative field that permits

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[403] Ibid., p. 27.

[404] Ibid., p. 27.

[405] Ibid., p. 27.

[406] These forces, actions and external references refer to the informational data of program requirements, site necessities and the visual or conceptual sources imported from disciplines other than architecture itself. For an elaborate discussion of the subject see previous sub-chapters.

[407] Stan Allen. "Terminal Velocities: The Computer in the Design Studio" In, John Beckmann. (Ed.) *The Virtual Dimension: Architecture, Representation, and Crash Culture,* New York: Princeton Architectural Press, 1998, p.248.

modification, manipulation and reconfiguration during the architectural process.[408] Allen states that the operativeness of the architectural object is due to the fact that it;

> …is a collection of commands as opposed to the result of a series of projections. Instead of a finite number of representations constructing an object (either in mind or in world) there is already an object (itself made up of a nearly infinite number of discrete elements) capable of generating an infinite number of representations of itself….As a consequence of this, the effect of working on the computer is cumulative. Nothing is lost. Elements and details are continuously added, stored and filled in perfect transparency. Instead of proceeding from the general to the specific; the designer moves from detail to ensemble and back again, potentially inverting traditional design hierarchies.[409]

Henceforth, in opposition to the conventional modes of design in which every step from sketching to detailed drawing is made to preserve the clarity and unity of the of the architect's initial idea or the concept, contemporary digital technologies are seen to allow architects to alter anytime both the quantitative and the qualitative aspects of the architectural process or of the architectural object.[410] Since digital technologies are accepted to produce changes in kind, not just in number, they are assumed to render the architectural process irreversible.[411] In other words, the assertion on the generativeness of such technologies is made not due to the possibilities that create variation in quantity, but it is attributed mainly to the creative possibilities of these technologies that cause in every step a novel result and turn the architectural process to an open ended evolution. As regards, it is claimed that in every evolutionary point of the digital process there appears the

[408] Ibid., p.248. (italics are mine)

[409] Ibid., p.248.

[410] Ali Rahim. *Catalytic Formations: Architecture and Digital Design*, p.25.

[411] Ibid., p.25.

possibility of a unique creation that cannot be estimated previously. As declared by Ali Rahim, “at no point in the process is the final result known: on the contrary, the hope is that the techniques used intelligently will generate unanticipated, catalytic effects.”[412]

Therefore, the architectural object or the final form, rather than being a manifestation of the architect’s unique intention and ideation is accepted to become the direct result of a “computational”, “indeterminant”, “emergent”, “evolutionary” procedure.[413] Peter Saunders asserts that the concentration of architecture is seen to move away from the object to the process, from the final form or result to the system and from the practitioner architect to the developmental system of organization.[414] Through this changing concentration of concerns in the architectural process, the production of form is accepted to take a new route that departs from the authority of the architect and disciplinary conventions.

Anthony Vidler argues that the new possibilities brought about with digital technologies are accepted as the new abilities of architectural production that exceed the limits of the traditional “functionalist” versus “formalist” debate.[415] As regards different techniques of digitalization are seen as the signals of the

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[412] Ibid., p.25.

[413] In the course of contemporary architecture the antinomy between computational and indeterminant process is assessed with respect to the generative biological models that include random factors in generation of the indeterminant variety. However, as in the translation of this biological convention to an architectural model, the randomness factor is also determined by computational technologies, it can be asserted that the discussions on this antinomy still require a critical insight.

[414] Peter T. Saunders. “Nonlinearity: What It Is and Why It Matters,” in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p.115.

[415] Anthony Vidler. “Technologies of Space/Spaces of Technology,” *The Journal of the Society of Architectural Historians*, Vol. 58, No. 3, Architectural History 1999/2000. (Sep., 1999), p. 483.

"emergence of a sensibility toward technology that combines a new "formalism" concerned with the spatial implication of plotting, mapping, and morphing and a new "functionalism" that exploits the apparently limitless potential of animation and graphing programs to accept the input of various internal and external forces as at once form and its technological implications."[416]

Henceforth, the potentials of digital technologies have become to be seen as the marks of a change in the methodology of architectural process and formal production. Although the architectural process directed by digital technologies is accepted to include "function" and "image/form", in opposition to the conventional methodologies, it is assumed that in this new process the architectural form/container is not conceived as a necessary result of formal and functional intervention.[417] As declared by Ali Rahim rather than composing a form by adding together blocks of program, nonlinear techniques promoted by digital technologies are seen to "strive to generate a whole that exceeds its individual components, yielding unexpected forms, materials, and modes of inhabiting space."[418] Accordingly, unpredictable results of contemporary techniques and the numeric control that lies behind the emergence of unforeseeable results became the main challenge for architects working with digital technologies.

> Designers can see forms as a result of reactions to a context of forces or actions…There is, however, nothing automatic or deterministic in the definition of actions and reactions; they implicitly create fields of indetermination from which unexpected and genuinely new forms might emerge –unpredictable variations are generated from the built multiplicities…It is precisely this ability of "finding a form" through

[416] Ibid., p. 483.

[417] Peter Eisenman. "Process of Interstitial," in *Blurred Zones: Investigations of the Interstitial*. New York: The Monacelli Press, 2003, p. 97.

[418] Ali Rahim. *Catalytic Formations: Architecture and Digital Design*, p.26.

> dynamic, highly non-linear, indeterministic processes that gave the digital media a critical generative capacity in design. Even though the technological context of design became thoroughly externalized, its arresting capacity remains internalized.[419]

Accordingly, Branko Kolarevic asserts that digitally generated forms signal a radical departure from centuries old traditions and norms of architectural design:[420]

> In a radical departure from centuries old traditions and norms of architectural design, digitally generated forms are not designed or drawn as the conventional understanding of these terms would have it, but they are calculated by the chosen generative computational method. Instead of modeling an external form, designers articulate an internal generative logic, which then produces, in an automatic fashion, a range of possibilities from which the designers could choose an appropriate formal proposition for further development.[421]

The highly appreciated geometric interaction of objects is seen to be the basic tenet of the computer generated formal production, the search for an emergent form and the indeterminate generativeness of the architectural process.[422] Consequentially the production of form subjected to a perpetual revision through an exhaustive sequence of operations, i.e. transformation, decomposition, grafting, scaling, rotation, superposition, shifting, folding.[423] Henceforth, this nonlinear interaction of objects and forces is assumed to add a temporal dimension to the

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[419] Branko Kolarevic. "Designing and Manufacturing Architecture in the Digital Age" http://www.upenn.edu/gsfa p.119-120. last accessed in 10.07.06.

[420] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*, p. 13.

[421] Ibid., p. 13.

[422] Greg Lynn. "Geometry in Time" in Cynthia Davidson (Ed.) *Anyhow,* Cambridge and Mass: The MIT Press, 1998, p. 171.

[423] R. E. Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture" in Peter Eisenman. *Diagram Diaries,* p. 15.

architectural process instead of producing a determinant, unique result (which is a consequence of a static, linear process)[424] as in the case of traditional methodologies. Greg Lynn notes that, as a result of these nonlinear processes architectural form became "not only a manifestation of its internal, parameter driven relational logic, but *also a response* to dynamic, often variable influences from its environmental and socio-economic context; architectural form instead of being conceived as a stationary, inert construct, is *started to be regarded as* a highly plastic, mutable entity that evolves dynamically through its transformative interactions with external, gradient forces."[425]

In that respect the use of dynamic, nonlinear systems which are seen to be capable of producing self-organizing systems and structures is supposed to generate spontaneous orders and solutions as a result of the architectural process.[426] Essentially, what makes nonlinear systems more preferable for the contemporary architects is accepted to be the autonomy of the output. Contrary to the linear systems which are directly shaped by the acting forces and give the same result if the input forces are same in any case, non-linear systems are assumed to include random factors which cause the results to be dissimilar though the given factors are same.[427] Peter Saunders notes that the basic "characteristic feature of nonlinear systems is that they often have generic properties, i.e. properties which occur time and time again in different systems and in different contexts."[428] Unlike linear

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[424] Greg Lynn. "Geometry in Time" in Cynthia Davidson (Ed.) *Anyhow,* p. 172.

[425] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*, p. 19. (italics are mine)

[426] Peter T. Saunders. "Nonlinearity: What It Is and Why It Matters," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p.113.

[427] Ibid., p.114.

[428] Ibid., p.114.

systems that are shaped by the forces that act on them, nonlinear systems are seen as more autonomous processes which have generic properties.[429]

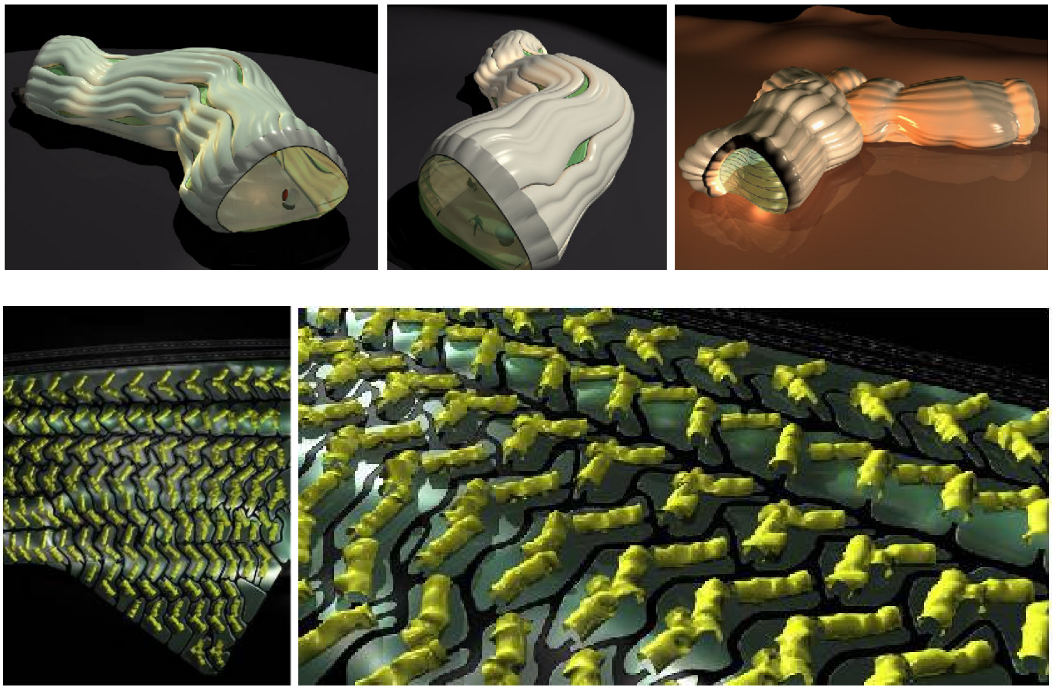

Figure 2.8: Off the road 5speed by Nox. **Source:** Ali Rahim (ed.) Contemporary Processes in Architecture, *Architectural Design,* Vol: 70, No. 3, June, 2000.

Regarding these new challenges which are seen to be the basic results of architects' utilization of nonlinear systems and models from diverse disciplines, Mark Burry expands both the definition and representation of architecture beyond tectonics.[430] Therefore, he claims that under the secure control of mathematical thinking, architecture's narrow definition of "the art and science of building"

[429] Ibid., p.114.

[430] Mark Burry. "Notes on the Non Standard: Numerical and Architectural Production Tomorrow" In Frédric Migayrou and Zeynep Mennan (Eds.), *Architectures Non Standard,* Paris: Editions du Centre Pompidou, 2003, p. 56.

turned out to be an insufficient designation when contemporary architects' utilization of new, diverse mathematical and biological models and methodologies are considered.[431]

3.3.2) Generative Systems: From Determinate Structures to Indeterminate Systems

Unlike the traditional attempts that were in search of unchanging essences of the visible world, the new mode of architectural production in the so called digital era is seen to appreciate visual change over the stable grounds, principles and foundations of architecture.[432] Indeed, as manifested by Mark Burry, the change is accepted as the only reality of contemporary architectural production aided by the numeric control of digital technologies.[433] As a consequence of this shift, the idea of "becoming" is assessed as the main source of this new reality that is emergent, unpredictable and dynamic. Therefore, the privileged role of a unified theory of "being" is put into erasure on behalf of the unstable but productive modes of "becoming."[434] On the other hand, this yet raising interest on the concept of "becoming" is seen to point out a shift for most disciplines including architecture to a new mode of thought which rejects the possibility of a unique ground that

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[431]Ibid., p. 56.

[432] Mark Burry. (1996) The Generation and Degeneration of Form using Caad: Uncertain Certainty, *Approaches to Computer Aided Architectural Composition*, Technical University of Bialystok, Bialystok, Poland, p. 84. Burry further adds that "in a world of such rapid change, perhaps the only effective gesture towards formal coherence is the paradoxical denial of any constants: the pluralistic response."

[433] Ibid., p. 84.

[434] For an elaborate discussion of the subject see previous chapter.

results in a unified theory and signals a new mode of pluralism that promotes multiplicities and interconnections.[435]

As regards, mainly taking the Deleuzian concept of the "machinic phylum" as the ground, the production of architectural form is started to be defined by self organizing processes that put into interaction these multiplicities and interconnections.[436] John Rachmann notes that for Deleuze, events never happen out of a *tabula-rasa*, but come out of an interaction or intersection of multiple lines.[437] Therefore, for the Deleuzian discourse the production of any form is seen to be never "disentangled in a single transparent plane given to a fixed external eye."[438] As a result of this distrust in a single performer/actor/operator/observer/creator in architectural production, there emerges a new emphasis on generative self-organizational systems of biology that internally embed the productive capacity in themselves.

The process of self-organization is defined as the internal organization of a system that "adapts to the environment to promote a specific function without being guided or managed from outside." [439] Essentially, in biology, it is outlined as the study of growth and development of organisms and also the genetic control of the

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435 Mark Burry. (1996) The Generation and Degeneration of Form using CAAD: Uncertain Certainty, *Approaches to Computer Aided Architectural Composition*.

436 Water Garden. "Reiser+Umemoto with David Ruy and Jeffrey Kipnis," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 45.

437 John Rajchman. "Out of the Fold," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 36.

438 Ibid., p. 36.

439 Michael Hensel. "Computing Self-Organization: Environmentally sensitive Growth Modelling," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 12.

cell growth and morphogenesis through redundancy and differentiation factors.[440] In other words, it is the study of the behavior and interaction of cells or elements that produce more complex structures and formal differentiation.[441] The critical characteristic of these biological self organizations is defined as: "small, simple components assembled together in three-dimensional patterns to form larger organizations that, in turn, self-assemble into more complex structures that have emergent properties and behavior."[442]

> Self-organizing systems typically display emergent properties, which arise when a number of simple entities or agents cooperate in an environment, forming more complex behaviors as a collective. Emergent properties arise when a complex system reaches a combined threshold of diversity, organization and connectivity.[443]

In studies of these systems, the organization of disconnected elements either in organic or inorganic structures are analyzed so as to reveal the critical points in which the elements co-operate to form a higher level entity.[444] This higher level entity identified with each emergent point in the process is seen to result in an unexpected form which is brought forth through the interaction of input elements. The same mathematical model that forms the deep/underlying structure of every transformation in the production of form is seen to be the basic principle and guide of self-organizing systems. As declared by Water Garden "the notion of the "machinic phylum" *(i.e. the term generally used for self organizing*

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[440] Ibid., p. 12.

[441] Ibid., p. 12.

[442] Michael Weinstock. "Self-Organization and the Structural Dynamics of Plants," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 27.

[443] Michael Hensel. "(Synthetic) Life Architectures: Ramification and Potentials of a Literal Biological Paradigm for Architectural Design," in *AD: Techniques and Technologies in Morphogenetic Design.* Helen Castle (ed.) Vol: 76, No: 2, p. 19.

[444] Water Garden. "Reiser+Umemoto with David Ruy and Jeffrey Kipnis," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 45.

processes/systems) thus blurs the distinction between organic and non-organic life. This material geometry constitutes the "primitive", through which a hierarchical series of global and local transformations is expressed."[445]

In that regard, the "machinic phylum" turning out to "an abstract DNA" or "vertebrate" becomes the coding function of each and every particular result in the production of form.[446] As in nature's production of forms this abstract coding system (which is mathematical or geometric in character) serves to produce divergence, also in architecture the production/use of a similar code is accepted to give rise to unexpected, diverse and more essentially emergent results.

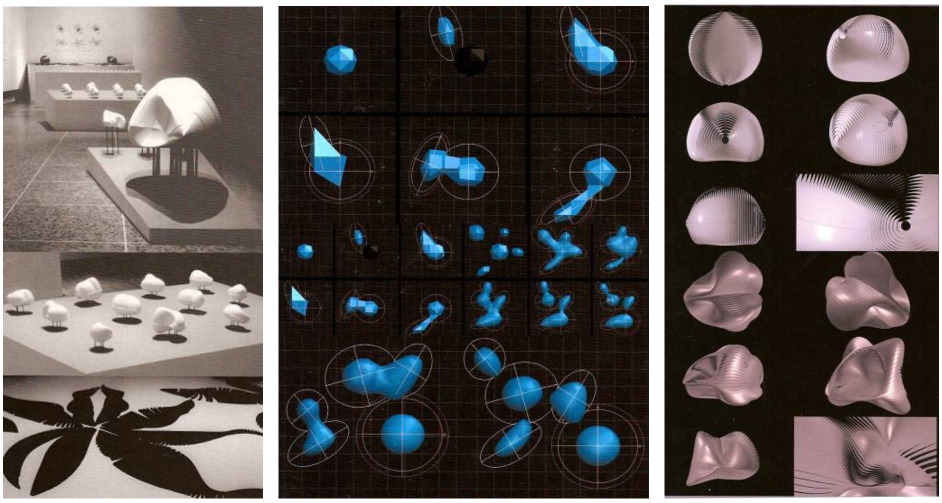

Figure 2.9: The emergence of form. **Source:** Peter Zellner, *Hybrid Space : New Forms in Digital Architecture*, New York: Rizzoli, 1999, pp: 138-142.

The concept of "emergence" is outlined as the "explanation of how natural systems have evolved and maintained themselves and a set of models and

[445] Ibid., p. 45. (italics are mine)

[446] Manuel De Landa. "Deleuze and the Use of Genetic Algorithm in Architecture" http://boo.mi2.hr/~ognjen/tekst/delanda2001.html. p.5.

processes for the creation of artificial systems that are designed to produce forms and complex behavior and perhaps even real intelligence."[447] Identified with the properties of a system that cannot be deduced from its parts, it is utilized in architecture "as a technique of evolution" and morphogenesis.[448] This evolutionary technique in architecture's formal production in that regard is defined as the development of a "population of forms" from which the fittest has evolved.[449]

> What is important is that the design tools are able to capture both the underlying design rules from which a range of potential solutions can be explored, and facilitate how this "solution space" can be refined into a suitable candidate for construction.[450]

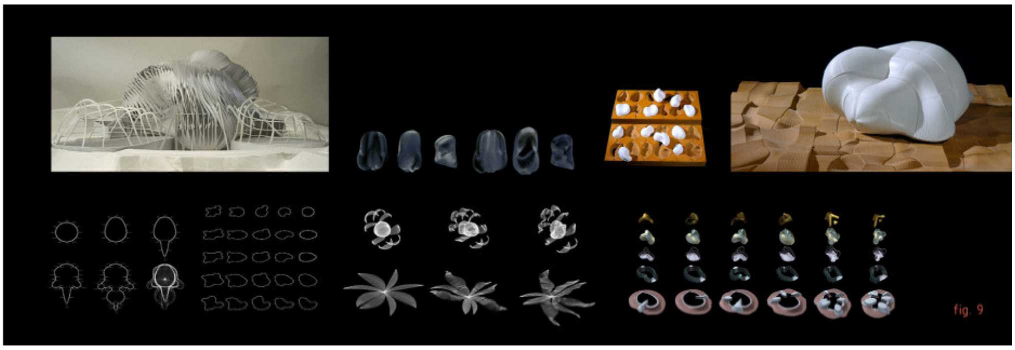

Figure 2.10: Embriologic Houses by Greg Lynn. **Source:** Ali Rahim (ed.) Contemporary Processes in Architecture, *Architectural Design,* Vol: 70, No. 3, June, 2000.

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[447] Michael Hensel. "Introduction: Towards Self-Organizational and Multiple-Performance Capacity in Architecture," in Techniques and Technologies in Morphogenetic Design." (ed. Helen Castle) *Architectural Design*, Vol. 74 No. 3, 2004, p. 6

[448] Ibid., p.6

[449] Michael Weinstock. "Morphogenesis and the Mathematics of Emergence," in Techniques and Technologies in Morphogenetic Design. (ed. Helen Castle) *Architectural Design,* Vol. 74 No. 3, 2004, p. 12.

[450] Achim Menges. "Instrumental Geometry," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 47.

Rather than to build the first idea and operate through it, by means of the codification of the "intellectual process of self-organizing systems" via externalization, generalization and abstraction,[451] a new mode of production is claimed to have been achieved in architecture. This alternative morphogenetic approach to architectural design that entails "unfolding morphological complexity and performative capacity from material constituents"[452] is assumed to deprive the authority of traditional architectural methodologies that necessitate a direct causality between the initial idea and the resultant form. In that respect, as claimed by Branko Kolarevic, it is accepted that these "contemporary approaches to architectural design have abandoned the determinism of traditional design practices and have embraced the directed, precise indeterminacy of new digital processes of conception."[453] The possibility to formulate generative systems of formal production, the ability to control its behavior over time and further the selection of forms that emerge from these operations, turn out to be the main challenge for architects. External information, whether economic, cultural or social, is put into use in biological, chemical or mathematical systems of organizations to generate architectural form. Though the information taken as the source for the production of architectural form can have some generic properties, since it is subjected to the processes of "de-formation" and "trans-formation" which are driven by the very same relations, the inevitable divergence in the products is claimed to be reached. [454]

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[451] Ibid., p. 44.

[452] Achim Menges. "Polymorphism," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 79.

[453] Branko Kolarevic. (Ed.) "Digital Morphogenesis," *Architecture in the Digital Age: Design and Manufacturing*, p. 26.

[454] Ibid., p. 26.

These developments in the digital process are seen to open up new territories for conceptual, formal and tectonic explorations of the architectural process, articulating an architectural morphology that focuses on the emergent and adaptive properties of form.[455] Therefore, Branko Kolarevic asserts "the emphasis shifts from the "making of form" to the "finding of form" which various digitally-based generative techniques seem to bring about intentionally in the realm of form, *and through which* the stable is replaced by the variable, singularity by multiplicity."[456] As a consequence, Kolarevic claims that "the predictable relationship between design and representation are abandoned in favor of computationally generated complexities."[457] The question of form is then reduced to a mere matter of experience.[458] The experiential realm of the digital architectural process is seen as an extended possibility in achieving diversity in the final form or differentiation in the formal vocabulary.

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[455] Ibid., p. 13.

[456] Ibid., p. 13, (italics are mine).

[457] Ibid., p. 13.

[458] Michael Hensel. "Finding Exotic Form: An evolution of Form Finding as a Design Method," and Michael Weinstock. "Morphogenesis and the Mathematics of Emergence," in Techniques and Technologies in Morphogenetic Design. (ed. Helen Castle) *Architectural Design*, Vol. 74 No. 3, 2004. Although Hensel confirms the yet raising interest of architects to experiential possibilities, he defines possibilities of digital experience not as reduction, but as an extension of the definitive boundaries of architectural discipline.

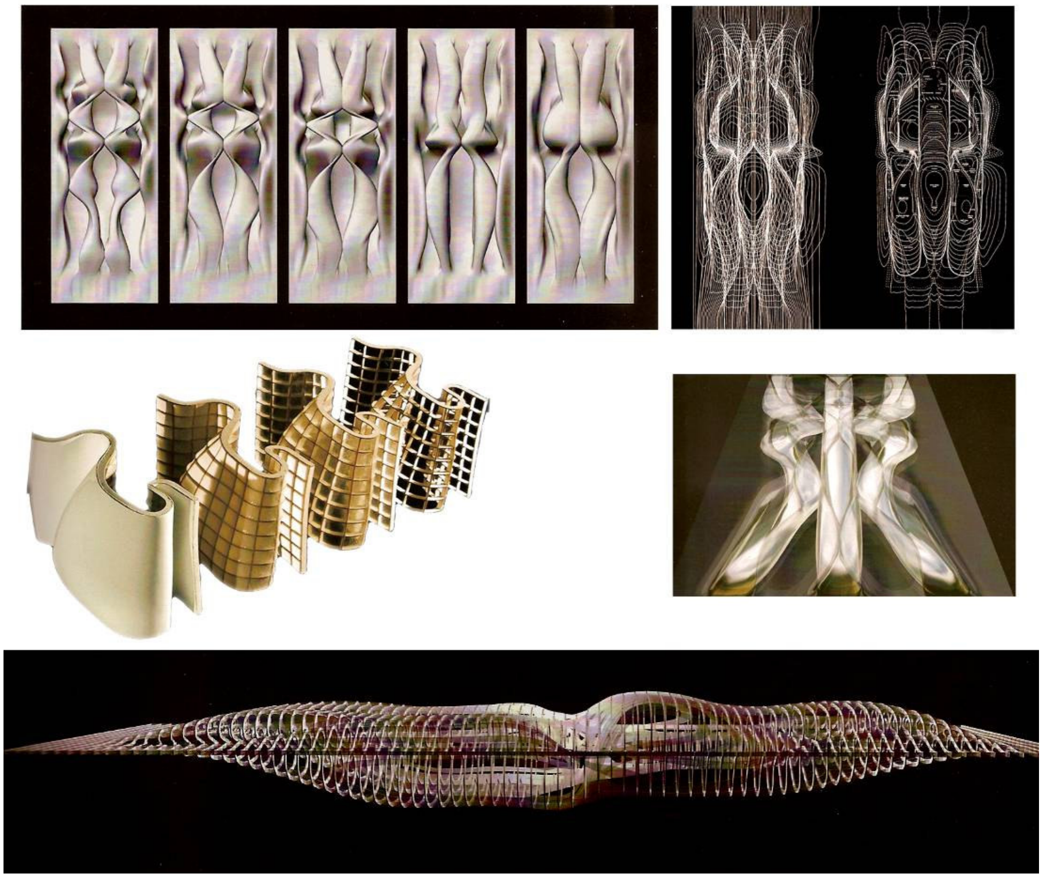

Figure 2.11: A New Playhouse for the Royal Theatre in Copenhagen by Achim Menges, Lip Khoon Chiong and Morten Rask Gregersen. **Source:** Yu-Tung Liu (ed). *Demonstrating Digital Architecture*, Boston: Birkhäuser, 2005, pp: 153-155.

Under the influence of the twentieth century mathematician and biologist René Thom, for the examination of nonlinear systems, the creation or better the development and the emergence of form became the center focus for contemporary architects.[459] The end of mechanistic biology and the discovery of evolutionary structures in nature's creation of form raised the oppositions to the view that;

[459] Peter T. Saunders. "Nonlinearity: What It Is and Why It Matters," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p. 114.

> …the whole is the sum of its parts that cause and effect are simply related, and can be neatly isolated. The discovery ended the quest for the material basis of the units of heredity –the genes- that are supposed to determine the characters of organisms and their offspring, thus firmly establishing the predominance of the genetic determinist paradigm. The subsequent flowering of molecular biology gave rise to the present era of recombinant DNA research and commercial genetic engineering biotechnology.[460]

As regards, Weinstock notes that "morphogenesis, has become much more central to evolutionary theory than in Darwin's thesis."[461] The sequential phase of the process is considered to be a virtual DNA[462] which is later to be synthesized with virtual genes. The new mode of "architectural operation" termed by Manuel de Landa as "populational thinking" is seen to provide architecture a new mode of reasoning that presents a synthesis of Darwinian and Mendelian theories.[463] Termed as "evolutionary biology", this new approach to material systems and organizations focuses on "redundancy" as a deep strategy implemented at many levels, in multiple and complex hierarchical material arrangements and differentiation to achieve robust and stable structures, unlike traditional conceptions that sought to minimize materials and to achieve simplicity of structural organization, and the standardization of components and members.[464] The emphasis on the "redundancy factor" in morphogenesis and differentiation, in turn resulted in a shifting interest from deterministic to in-deterministic or "stochastic" processes. As regards, developing processes that include small

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[460] Mae-Wan Ho. "The New Age of Organism," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 117.

[461] Michael Weinstock. "Morphogenesis and the Mathematics of Emergence," in Techniques and Technologies in Morphogenetic Design. (ed. Helen Castle) *Architectural Design*, p. 12.

[462] Manuel De Landa. "Deleuze and the Use of Genetic Algorithm in Architecture," p. 2.

[463] Ibid., p.2.

[464] Michael Weinstock. "Self-Organization and the Structural Dynamics of Plants," in *AD: Techniques and Technologies in Morphogenetic Design.* Helen Castle (ed.) Vol: 76, No: 2, p. 27.

random mutations over many iterations became a significant "evolutionary" strategy for architectural production.[465] Therefore, the "stochastic processes" i.e. the processes which will never repeat an identical output are seen to take the place of deterministic processes that always produce the same output from a given starting condition.[466] In that regard "evolutionary simulation" is accepted to replace "the design methodology" since architects are encouraged to use software developed to this end to breed new forms rather than to specifically design it.[467] Therefore, "rather than being "given form" on some assumed rational basis" as asserted by Mark Burry, buildings are "allowed to "take form" as a frank response to place and use and us."[468]

Therefore, Burry claims, entirely new sorts of objects and complex results can be achieved although the acting forces called "genetic patterns", are simple and few in number.[469] As regards it is accepted that the use of a proper "genotype" will ensure the anticipated variations in the "phenotypes".[470] Genetic patterns are accepted to form the essence of an evolutionary architectural process which brings forth the self generation of forms.[471] These genetic patterns, mostly geometric and

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[465] Ibid., p. 27.

[466] Ibid., p. 27.

[467] Manuel De Landa. "Deleuze and the Use of Genetic Algorithm in Architecture," p. 1.

[468] Mark Burry. (1996) The Generation and Degeneration of Form using Caad: Uncertain Certainty, *Approaches to Computer Aided Architectural Composition*, p. 80.

[469] Peter T. Saunders. "Nonlinearity: What It Is and Why It Matters," in Giuseppa Di Cristina (ed.) *Architecture and Science*, p.112.

[470] Achim Menges. "Instrumental Geometry," in *AD: Techniques and Technologies in Morphogenetic Design,* p. 44.

[471] Ibid.

mathematical in character, are seen to have both a local and global role in the integrated dynamic of pattern and form in self-organized morphogenesis.[472]

According to John Frazer, through genetic algorithms, "architectural concepts are expressed as a set of generative rules and their evolution and development can be digitally encoded."[473]

> The key concept behind the evolutionary approach to architecture is that of the genetic algorithm, "a class of highly parallel evolutionary, adaptive search procedures" as defined by Frazer. Their key characteristic is a "stringlike" structures equivalent to the chromosomes of nature "to which the rules of reproduction, gene crossover and mutation are applied. Various parameters are encoded into "a string like structure" and their values changed, often randomly, during the generative process. A number of similar forms "pseudo organums" are generated, which are then selected from the generated populations based on a predefined "fitness" criterion.[474]

The use of the genetic algorithm in architecture is then seen to propose an artificial simulation of nature in its highly appreciated productivity and complexity.[475] Achim Menges states that the use of genetic algorithms in the architectural process composes of four phases that start with the encoding of the self-organizational characteristics of the materials and the material systems in order to retain these characteristics across all the system instances to produce

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[472] Michael Weinstock. "Morphogenesis and the Mathematics of Emergence," in Techniques and Technologies in Morphogenetic Design.(ed. Helen Castle) *Architectural Design*, p. 17.

[473] Branko Kolarevic. (Ed.) "Digital Morphogenesis" *Architecture in the Digital Age: Design and Manufacturing*, p. 23. Originally in, John Frazer. *Evolutionary Architecture,* London: Architectural Association, 1995.

[474] Ibid., p. 24.

[475] Achim Menges and Michael Hensel. "Material and Digital Desgin Synthesis: Integrating Material Self-organization, Digital Morphogenesis, Associative Parametric Modeling and Computer Aided Manufacturing," in *AD: Techniques and Technologies in Morphogenetic Design.* Helen Castle (ed.) Vol: 76, No: 2, p. 89.

parametric variables of the digital model.[476] Secondly, these geometric relations that characterize the setup and constitute the digital model are informed by the computer-aided manufacturing (CAM) constraints of the material components in order to directly manufacture the digitally defined system.[477] In the third phase of the genetic process, the digital model which is geometrically characterized by the material behavior and the materialization processes starts to populate geometric host environments (i.e. surfaces or branch-like geometric structures) in order to form larger assemblies.[478] Further in the process, various generations of the system is stated to evolve in response to the increasing level of articulation of the input geometry. [479] In the last phase of the genetic process the data that belongs to physical reality is also encoded as geometric parameters to be put into use as the specific determinants of a particular project.[480] The direction of the sun, the intensity of the wind or voice etc., which are geometrically parametrized and thus quantified, are put into interaction with the initial digital model to develop the environment responsive architectural object.[481] These new challenges in geometric decoding and genetic encoding of the material systems are accepted to offer a novel relationship with the physical reality causing a resolution in the belief of a unified theory of geometrically created and ordered universe. As regards, the architectural object is started to be conceived as a *response* to the interaction of geometric multiplicities of physical systems and components rather than as a *reflection* of a higher mathematical/geometric order that the nature/universe embeds.

[476] Ibid., p. 89.

[477] Ibid., p. 89.

[478] Ibid., p. 89.

[479] Ibid., p. 89.

[480] Ibid., p. 89.

[481] Ibid., p. 89.

Accordingly, Achim Menges asserts that through this shift in conception, the difference between the natural and the manufactured has disappeared,[482] since the geometric properties and relations are supposed to be the only determinants for both processes. To decode the "intellectual foundations" of both processes and to encode them in geometric terms[483] has started to be seen as the only essential requirement for productive and emergent results in both processes.

> The arrival of parametric digital modeling changes digital representations of architectural design from explicit geometric notation to instrumental geometric relationships. Architects are beginning to shift away from primarily designing the specific shape of a building to setting up geometric relationships and principles described through parametric equations that can derive particular design instances as a response to specific variables, expressions, conditional statements and scripts.[484]

As observed by van Berkel and Bos, at the hearth of this contemporary architectural production undergoes an instrumentalization process that reduces global imagination into contemporary organizational structures and the new public mediated space into contemporary architectural effects.[485] The elevation of created formal effects over meanings, structures and unity of the architectural image, work through the destabilization of traditional norms and principles on which architecture grounded itself over centuries.[486] Diagram or diagrammatic practice within this destabilization process is seen to hold a crucial scrutiny/focus

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[482] Michael Weinstock. "Self-Organization and Material Construcions," in *AD: Techniques and Technologies in Morphogenetic Design,* p. 41.

[483] Achim Menges. "Instrumental Geometry," in *AD: Techniques and Technologies in Morphogenetic Design,* p. 43.

[484] Ibid., p. 43.

[485] Ben van Berkel and Caroline Bos. *Imagination: Liquid Politic*. Amsterdam: UN Studio and Goose Press, 1999, p. 16-17.

[486] Ben van Berkel and Caroline Bos. *Effects: Radiant Synthetic*, p. 24.

on the way to unfold the ascribed meaning to architectural image and production. Its non-representational, non-expressive, a –signifying generative character thus is accepted to challenge architects to perform without any reference to historically loaded principles and norms of architecture. As regards, the next sub-chapter will focus on the role of the new diagrammatic technique in architecture both as a representational tool and as a generative technique.

3.4) The Architectural Process as Information Management

3.4.1) Diagrams: Extending the Limits of Vision and Visual Representation

The utilization of mathematical layout and relations in contemporary architecture finds its visualization in generative diagrams of formal production. However, unlike any previous visualization technique utilized in architecture, diagrams are mostly regarded as lined networks of relationships that are completely vague in *formal expression*.[487] With reference to their non-expressive nature, they are considered as "informational nodes" and "codes" of the world that do not impose themselves on matter directly.[488] Diagrams in that regard, are accepted as visualization devices that integrate different functions and information through interaction and relation of forms.[489] However the use of diagrams as a mediator between information, function and form is regarded to radically depart from its historical utilizations.[490] The departure can be asserted that has a twofold extension that finds its reflection in two historical modes of abstraction: (1) the departure from the conventional modes of representation techniques and (2) the departure from the typological practice.

Accusing traditional modes of representation techniques of being passive recording mediums, these new visualization tools are claimed to have an active

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[487] Lars Spuybroek. *Nox: Machining Architecture,* New York: Thames and Hudson, 2004, p. 2.

[488] Ibid., p. 2.

[489] Peter Eisenman. "Diagrams of Interiority," in Peter Eisenman. *Diagram Diaries,* New York: Universe Publishing, 1999, p. 52.

[490] Peter Eisenman. "Diagrams of Anteriority," in Peter Eisenman. *Diagram Diaries.* New York: Universe Publishing, 1999, pp: 37-43. The contemporary use of diagrams in architectural production is mostly compared with typological practice or the functional schemas of modern period.

and generative role during the architectural process.[491] As regards, unlike the traditional techniques of representation that offer an abstraction of the initial idea and a precise guide for construction, these new visualization tools, without having any particular indication to the final form, are supposed to operate during every phase of architectural process. In that respect, instead of being a medium or a tool for projecting the already developed idea of the architect, diagrams are accepted as performative devices that carry condensed information[492] of site, program, function or the data of an external source. Through the visualization and mathematical decoding of existing information that is supposed to be the basics of an active methodology, the inputs that gave architecture its final shape are claimed to take a new form in diagrammatic practice that is practically transformable, modifiable and readily applicable to the end result.

[491] Lars Spuybroek. *Nox: Machining Architecture*, p. 2.

[492] Ben van Berkel and Caroline Bos. *Technique: Network Spin*, p. 19.

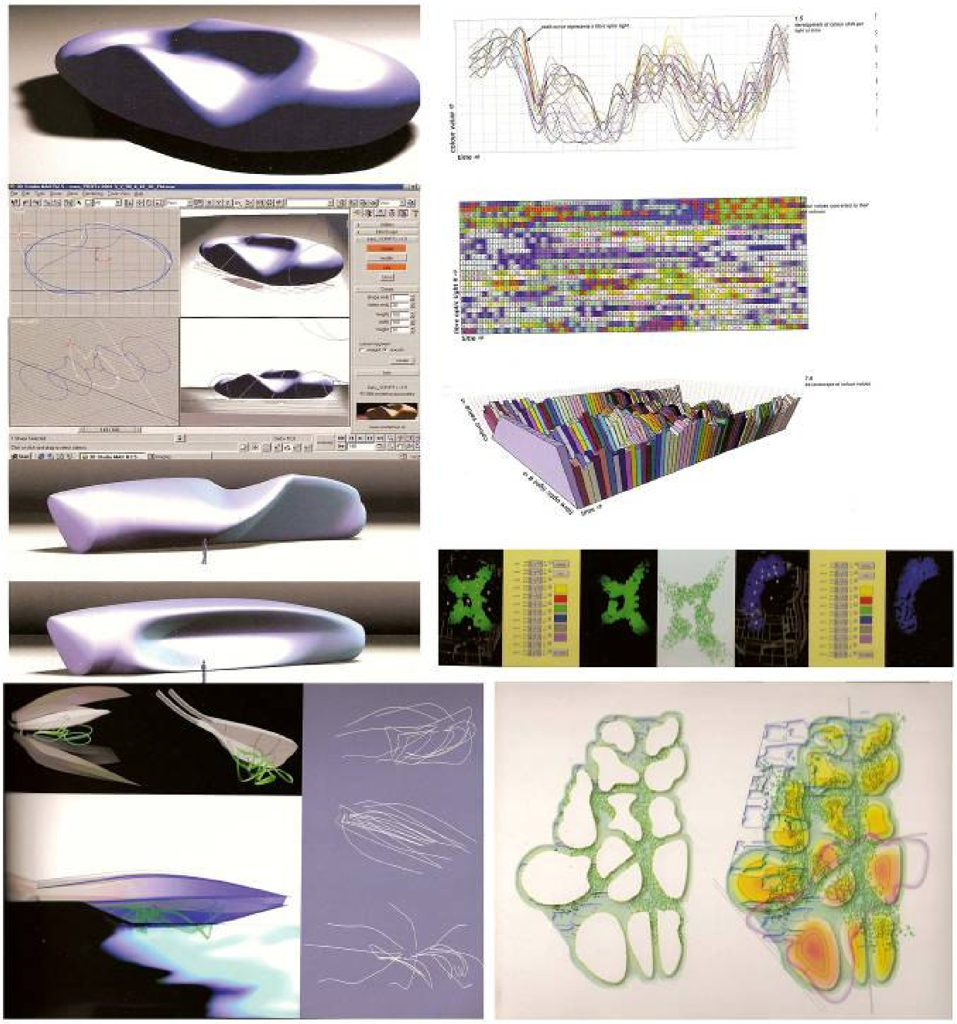

Figure 2.12: Generative diagrams. **Source:** Peter Zellner, *Hybrid Space: New Forms in Digital Architecture*, New York: Rizzoli, 1999, pp: 72-80.

Therefore diagrams are accepted to become the mark of the shift from all kinds of preliminary representation techniques like drawing, sketching and modeling towards "generative diagramming."[493] Since in a diagrammatic process, the representation and the "signification" of an architectural image are continuously

[493] Peter Eisenman. "Diagram an Original Scene of Writing," in Peter Eisenman. *Diagram Diaries,* p. 27.

postponed,[494] diagrams are mostly regarded as a resistance to the hegemony of vision and visual representation. The denial of the traditional modes of representation techniques because of their strict bound with material phenomena and their undeniable connection with the visual experience thus became the main challenge for contemporary architecture that declares diagrams as "non-visual drawing techniques."[495] Lars Spuybroek notes that diagrams being "non-visual drawing techniques" (that do not base on optical abstractions of later to be realized forms but mainly depend on informational visualization techniques), place themselves at the interior of a process instead of the exterior of a sensed form.[496]

> Unlike classical theories based on imitation, diagrams do not map or represent already existing objects or systems but anticipate new organizations and specify yet to be realized relationships. The diagram is not simply a reduction from an existing order. Its abstraction is instrumental, not an end in itself. Content is not embedded or embodied but outlined and multiplied. Simplified and highly graphic, diagrams support multiple interpretations. Diagrams are not schemas, types, formal paradigms, or other regulating devices, but simply place-holders, instructions for action, or contingent descriptions of possible formal configurations.[497]

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494 Lars Spuybroek. *Nox: Machining Architecture,* p. 3.

495 Ibid., p.1.

496 Ibid., p.1.

497 Stan Allen. "Diagrams Matter." *Any Magazine*, No. 23, 1998, p. 16.

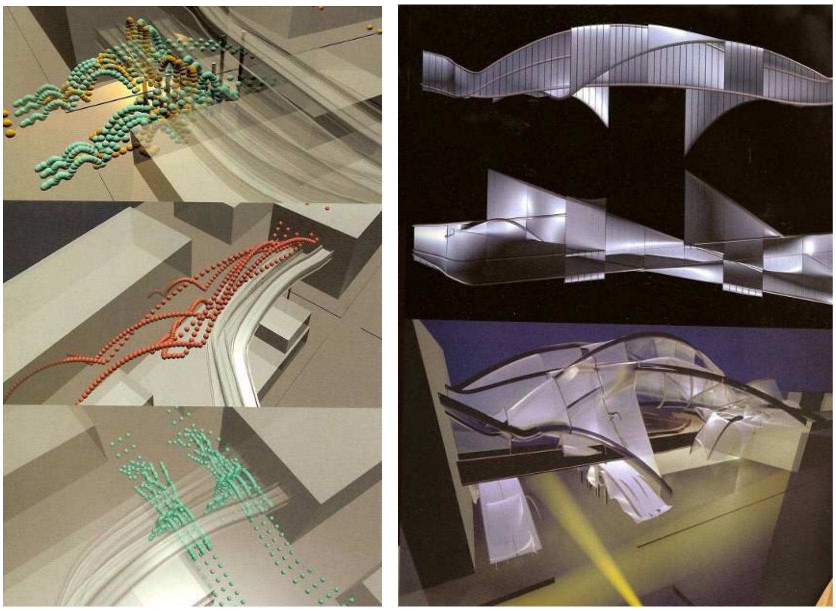

Figure 2.13: Generative diagramming. **Source:** Peter Zellner, *Hybrid Space: New Forms in Digital Architecture*, New York: Rizzoli, 1999, pp: 148,149.

Accordingly, Stan Allen asserts that the final image of the architectural object is asserted to have continuously postponed as the form continuously changes and re-forms itself with respect to the external forces and their effects.[498] Instead of producing the architectural form in consideration with its final expression as in the case of traditional methods, the focus in diagrammatic strategies is claimed to move to the process and its generative and productive possibilities/potentials. In that regard, architecture's departure from its own image and this image's loaded meaning is put forward as the most essential achievement of the contemporary architectural production based on diagrammatic practice.[499] Therefore in diagrammatic practice, the architectural object being a consequence of an indeterminant, accidental but generative process is claimed to displace the

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[498] Ibid., p. 16.

[499] Peter Eisenman. "Diagrams of Anteriority," in Peter Eisenman. *Diagram Diaries,* pp: 37-43.

symbolic value/meaning of its own image as the representation of a higher order, function, culture, language or social code.[500] The act of describing the architectural object out of any symbolic meaning or signifying mechanisms is termed by Tafuri as *"architecture dans le boudoir",* the ultimate intent of which he states, is "reclaiming the dimension of the object and its character as unicum by removing it from its economic and functional contexts; by marking it as an exceptional –and thus surreal- event by placing it between parentheses within the flux of "things" generated by the system of production."[501]

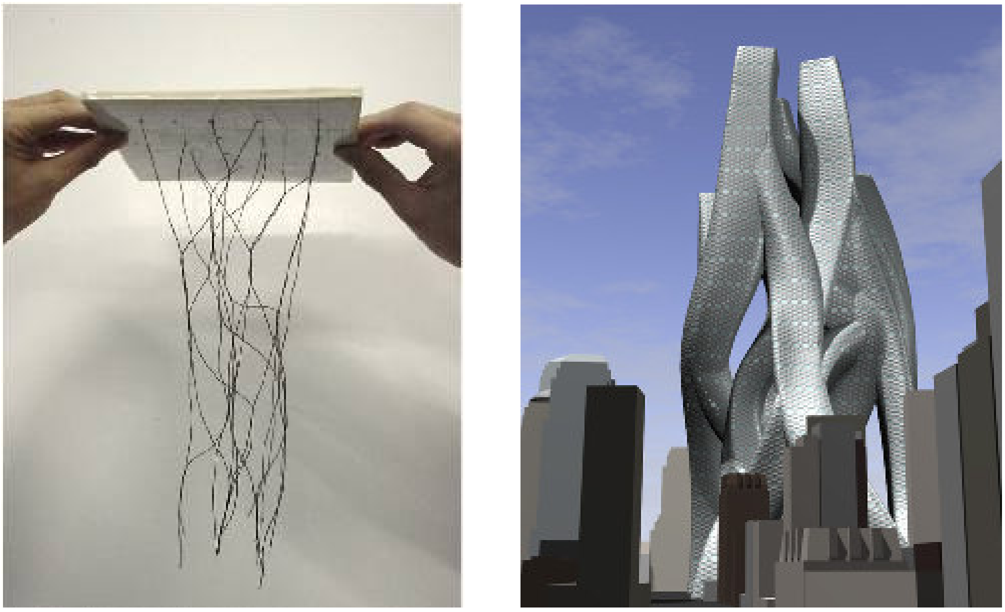

Figure 2.14: Oblique World Trade Center, (New York) by Nox. Different experimental sources in formal creation, **Source:** http://www.noxarch.com/flash_content/flash_content.html, last accessed in 05.12.07.

[500] Ibid., pp: 37-43.

[501] Manfredo Tafuri. "L'architecture Dans le Boudoir," in *The Sphere and the Laybrith.* Trans: Pellegrino d'Acierno and Robert Connolly, Cambridge and Mass: The MIT Press, 1987, p. 282.

As regards, in diagrammatic practice it is claimed that once accepted dictums of architectural production that define the final form as the embodiment of a higher order, as the exact solution of a particular function or as the most appropriate tool of communication give way to the disparate statements that change through each individual experiment.[502] The production of the architectural object turning out to an individual enterprise hence became a closed system of formal experimentation the only reference of which is nothing other than itself.[503] The utmost definition of the architectural object in such a production is made by Eisenman as the "self referential sign" that composes itself only of geometric relations (of architectural elements without any reference to the function, structure or beauty).[504]

3.4.2) Diagrams: Merging Content and Expression

As observed by Lynn, the emphasis on the interactive and performative role of diagrams is mostly made with reference to the Deleuzian concept of the "abstract machine."[505] The abstract machine that consists of both content and expression in Deleuzian framework, is used with reference to a diagrammatic procedure that is "self determinant" and "generative".[506] Deleuze defines abstract machines as such,

> A true abstract machine has no way of making a distinction within itself between a plane of expression and a plane of content because it draws a single plane of consistency which in turn formalizes contents and expression according to strata and reterritorialization. The abstract

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[502] Peter Eisenman. *Diagram Diaries.* New York: Universe Publishing, 1999.

[503] Peter Eisenman. "Aspects of Modernism: Maison Dom-ino and the Self Referential Sign," in *Oppositions Reader: Selected Readings from A Journal for Ideas and Criticism in Architecture 1973-1984.* Ed. K. Michael Hays, New York: Princeton Architectural Press, 1998, p. 191.

[504] Ibid., p. 191. Eisenman uses the terms function, structure and beauty with reference to the Vitruvian counterparts: utilitas, firmitas, venustas.

[505] Greg Lynn. "Geometry in Time," in Cynthia Davidson (Ed.) *Anyhow,* p. 169.

[506] Gilles Deleuze and Felix Guattari. *A Thousand Plateaus: Capitalism and Schizophrenia*, Trans: Brian Massumi. Minneapolis: University of Minnesota Press, 1993, p. 141.

> machine in itself destratified, deterritorialized; it has no form of its own and makes no distinction within itself between content and expression.[507]

An abstract machine therefore retaining "the deterritorialized content and the most deterritorialized expression" turns out to be a diagram that is neither substance nor form, neither content nor expression; but mere function and matter.[508]

> An abstract machine in itself is not physical or corporeal, any more than semiotic; it is diagrammatic. It operates by *matter*, not by substance; by function not by form… The abstract machine is pure Matter-Function –a diagram independent of the forms and substances, expressions and contents it will distribute.[509]

Therefore, through the deterritorialization and further reterritorialization of any constant signification, abstract machines are claimed to continuously treat the determinant relationship between signifier and signified and therefore the content and the expression.[510] Henceforth, unlike any causal action in which the content determines the expression or the expression reflects the content, in the abstract machines, the expression is liberated from the content.[511] As regards the independency of expression, Deleuze states that taking the full advantage of breaking its relationship with schemas of representation, information and communication forms a new category of productivity (that differentiates itself from the previous modes of production that assume a direct intervention/cause between the expressions and the content on the way to the production of meaning and sign value).[512] This new category of production termed by Deleuze as

507 Ibid., p. 141.

508 Ibid., p. 141.

509 Ibid., p. 141.

510 Ibid., p. 89.

511 Ibid., p. 89.

512 Ibid., p. 89.

"assemblage" therefore is claimed to erase the dialectical miracles (of any language) of the transformation of matter into meaning, content into expression and the social process into a signifying system.[513] Since the method of assemblage disregards any determining vertical structure or relationship (or the constants and universals that are produced by these structures and relationships), it is claimed to operate through a dynamic model rather than a linear mechanism.[514]

> Defined diagrammatically in this way, an abstract machine is neither an infrastructure that is determining in the last instance nor a transcendental Idea that is determining in the supreme instance. Rather, it plays a piloting role. The diagrammatic or abstract machine does not function to represent, even something real that is yet to come, a new type of reality.[515]

In Deleuzian thought this new type of reality which is significantly distinct from any previous reality conception, offers a new model of thought that departs from any sign or signifying procedure.

> Strictly speaking, therefore, there are no regimes of signs on the diagrammatic level, or on the plane of consistency, because form of expression is no longer really distinct from form of content. The diagram knows only traits and cutting edges that are still elements of content insofar as they are material and of expression insofar as they are functional.[516]

As regards, the generative, transformational, diagrammatic and machinic characteristics of the abstract machines[517] started to serve as an indiscernible essential of the contemporary diagrammatic architectural process. In that respect, the concept of "abstract machine" and "diagram" that are endlessly referred in the

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513 Ibid., p. 90.

514 Ibid., p. 91. (This model of operation is called by Deleuze as the "rhizome model".)

515 Ibid., p. 142.

516 Ibid., p. 142.

517 Ibid., pp: 145-146.

contemporary architectural discussions became to be used to exemplify the shift from a representational mode of architectural production to an instrumental one.[518] Lynn states that "the diagrammatic abstract machine is not representational, it does not represent an existing object or situation, but it is instrumental in the production of new ones."[519] This instrumentality of the diagrams on the other hand is accepted to function also for the production of new instrumental meanings that steer architecture away from "typological fixation".[520] In that regard, the instrumental use of diagrams in formal production is accepted as a departure from historically loaded concepts and conceptions of architecture.[521]

In that respect, diagrams seen as measureless, material free generative visualization tools and information gathering mediums are started to be utilized not to represent a given reality but to generate new ones.[522] It is claimed that in the body of diagrams, complexities of reality are merged not to represent that reality but to document it for further use.[523] In that regard, though being a mode of visualization, due to its departure from representational/expressional means, diagrams are regarded as operative mediums rather than documenting tools.[524] Therefore the unavoidable direct relationship between the modes of representation and the final product in traditional practice is claimed to have been exposed to a

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[518] Greg Lynn. "Geometry in Time" in Cynthia Davidson (Ed.) *Anyhow,* p. 169.

[519] Ben van Berkel and Caroline Bos. *Technique: Network Spin*, p. 21.

[520] Ibid., p. 19.

[521] Greg Lynn. "Geometry in Time" in Cynthia Davidson (Ed.) *Anyhow,* p. 169.

[522] Peter Eisenman. "Diagrams of Interiority," in Peter Eisenman. *Diagram Diaries,* pp: 47-59.

[523] Ibid., pp: 47-59.

[524] Ibid., pp: 47-59.

constant transformation in the body of diagrams.[525] Diagrams henceforth are claimed to be not representations or expressions of forms and formal relations but rather manifested as visualizations of a more complex relationship that functions through a network of interactions.

Figure 2.15: (Un) Plug Buildingby François Roche and Stéphanie Lavaux. **Source:** Marie-Ange Brayer, Frédéric Migayrou and Fumio Nanjo (eds.). *Archilab's Urban Experiments: Radical Architecture, Art and the City,* London: Thames and Hudson, 2005, pp: 270-271.

[525] Stan Allen. "Diagrams Matter," *Any Magazine*, No. 23, 1998, p. 16.

Ben Van Berkel and Caroline Bos also stress the use of diagrams as an instrumental method that goes beyond a mere representational design technique.[526] Enabling not only recording and documentation of the procedure but also easy manipulation, modification and transformation of the process they are claimed to be active, generative and dynamic tools rather than passive or static instruments.[527] Van Berkel and Bos state that:

> A representational technique implies that we converge on reality from a conceptual position and in that way fix the relationship between idea and form, between content and structure. When form and content are superimposed in this way, a type emerges. This is the problem with an architecture that is based on a representational concept; it cannot escape existing typologies.[528]

Therefore, this new method of production is seen to mark a radical break from the two key concepts of the so-called conventional architecture: type and program. Lynn states that the type has a more profound relationship with architecture's association with the notions of permanence and stability i.e. with the negation of time and its consequences.[529] The negation of the active role of time is claimed by Lynn has a direct relation with architecture's hope for idealized, unchanging, absolute rules and principles that are beyond and above the affective consequences of time.[530] He asserts that time in previous historical contexts is regarded as an independent, homogeneous envelop that covers all phenomena without actively impinging on anything.[531] Therefore he states timeless idealizations of form, function or expression are accepted to form a vertical

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[526] Ben Van Berkel and Caroline Bos. "Diagrams, Interactive Instruments in Operation," p. 21.

[527] Ibid., p. 21.

[528] Ibid., p. 21.

[529] Ali Rahim. *Catalytic Formations: Architecture and Digital Design*, p. 22.

[530] Lynn, Greg. *Animate Form.*

[531] Ibid.

structure that guide the practice through differentiation in repetition.[532] Such kind of a repetition termed by Somol as the repetition in *being* is assumed to rely on "an ideal of the origin or model, an economy of identity, and can be thought of as typologically driven (the vertical repetition of timeless precedents)."[533] In contrast to the repeated acts of typological creation of form, the repetition in diagrammatic practice, Somol claims, occurs "in motion divergent series and exists as a continual process of differentiating."[534] Thus Somol claims that while the typological creation points to a static moment of *being*, the diagrammatic performance is seen to advance through modes of *becoming*.[535] This new mode of production in that regard is accepted to offer a detachment from the highly appreciated universals of the architectural discipline, a release from the authority of vertical structures, and a liberation from the limited vocabulary of types, when compared to typologic creation.[536] As observed by Michael Hays,

> As for the discourse of type, we can see a development: out of the vertical imitation or repetition of presumably timeless precedents emerges a different kind of repetition, that of a complex, metonymic series of parts that exist in a continual process of differentiation…From the present perspective, what seems to have occurred is a de-differentiation at the level of typological technique as well, such that now a single, generic, emulsion supersedes the already limited field of object types.[537]

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[532] Ibid.

[533] R. E. Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture," In Peter Eisenman. *Diagram Diaries,* p. 9.

[534] Ibid., p. 9.

[535] Ibid., p. 9.

[536] Greg Lynn. *Animate Form.*

[537] K. Michael Hays. "Prolegomenon for a Study Linking the Advanced Architecture of the Present to That of the 1970s Through Ideologies of Media, the Experience of Cities in Transition, and the Ongoing Effects of Reification" *Perspecta,* p. 106.

Unlike conventional architectural thinking that relies on typology, a way of classifying buildings by their functions that dates back to the eighteenth century, diagrammatic practice is seen as a reactionary attitude towards any direct interpretation and expression of function in form.[538] Yet in diagrammatic practice the indispensable proponents of typological production that draw an undeviating, direct relationship between the essential function and the idealized form are discredited on behalf of the liberated possibilities of a non-expressive, non-representational, a-signifying process.[539]

In that respect, diagrams are seen as new instruments that provide architects with a new mode of autonomy.[540] Unlike the typological derivations that see the relationship between form and function as a universal attribute, diagrams are accepted to offer an interaction rather than a direct guiding relation.[541] In that regard, the cause and effect relationship between form and function is put aside on behalf of the generative capacity of the diagrams.[542] Since in diagrammatic practice neither the formal product is an outcome of functional relationships, nor the functional program is a validation of the form created, it is seen to offer new possibilities to architectural production. Diagrams in every step of the architectural practice, without directly representing the form or the function, are seen to enable architects to utilize essential relations and transform them into easily modifiable interactions. As regards, the contemporary exploration of time in diagrammatic architecture is claimed to offer a new possibility for architects to

[538] Ali Rahim. *Catalytic Formations: Architecture and Digital Design*, p. 78.

[539] Ibid., p. 78.

[540] R. E. Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture," In Peter Eisenman. *Diagram Diaries,* p. 10.

[541] Ibid., p. 10.

[542] Ibid., p. 10.

manipulate, modify and transform any idea without sticking on determinate conceptions, ideations or idealizations.

CHAPTER 4

CONCLUSION

Through the discussions that this study has made on architecture's involvement with mathematical concepts and relations, it can be asserted that either the practical or the theoretical achievements of this affiliation have occupied quite a significant part in architectural production throughout history. In that regard, the thesis asserts that the demonstrative strength of mathematical methodology, the self-evidence of its principles, the explanatory power of its premises, the predictive value of its mode of reasoning and its objective, rational, universal, absolute character have provided architecture with the ultimate source in its search for a foundational ground.[543] Though, on the one hand, the perfectness, ideality and accuracy of mathematical concepts and relations support the elevated role of mathematics in architectural practice, on the other hand its timeless, immutable, universal character has made mathematics the most profound basis for architectural theory.

Starting with the Greek tradition mathematical entities were accepted as ideal constructs of the mind that well comprehend with the reality of nature.[544] Till the nineteenth century developments in mathematics, either the explanation (Platonic or Aristotelian) or the systematization (Euclidean or Albertian) of physical reality/space in mathematical or geometric terms are seen to have ontological or

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[543] Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd. Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997.

[544] Bertrand Russell. *History of Western Philosophy*. London and New York: Routledge, 2007, p.43.

transcendental bounds.[545] As regards, the utilization of the ideal mathematical concepts either in architecture or in science has been seen as a symbol of a perfect order that Nature possesses.[546]

Although, for the initial affiliations of architecture with mathematics, the search for an objective ground that was endowed with mathematics was identified with the search for truth, through the developments in nineteenth century, the absolute, universal character of mathematics was put into conscious questioning.[547] These questionings on the foundational grounds of mathematics and mathematical reasoning have resulted in a paradigmatic shift reversing the value of mathematics from explanation of all physical reality, to an instrument the very supremacy of which was started to be conceived as a conventional compromise rather than an absolute truth.[548] Accordingly this paradigmatic shift in nineteenth century mathematics has given rise to the emergence of new possible geometries termed as "non-euclidian". The possibility of other geometries in consequence devaluated the elevated role of Euclidean and Cartesian geometries, bringing about new geometric possibilities for the explanation and analysis of space. These developments in nineteenth century mathematics have found reflection first in the shifting interest of contemporary architecture from Euclidean to non-euclidean space, and recently with the turn towards applied mathematics, in the instrumentalization of mathematical relations for architectural production.

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[545] Alberto Pérez-Gómez and Louise Pelletier. *Architectural Representation and the Perspective Hinge,* Cambridge, MA: The MIT Press, 1997, p.23.

[546] Morris Kline. *Mathematics: A Cultural Approach*. London: Addison-Wesley Publishing Company, 1962. p.15.

[547] John Henry. *The Scientific Revolution and the Origins of Modern Science*, New York: Palgrave, 2002, p.30.

[548] Elie Zahar. *Poincaré's Philosophy: From Conventionalism to Phenomenology,* Chicago: Open Court Publishing Company, 2001, p.70.

Though for the previous historical relations, the ontological or epistemological concerns had supported the transcendental status of mathematics for architectural practice and theory, for contemporary architectural production this relationship took a more instrumental shape that makes emphasis on the translation of physical reality (through numeric control of digital technologies) into a practical strategy.[549] As regards, unlike from the prior apprehensions of mathematics that were in search for the explanation of physical reality, the contemporary interest in architectural production turned out to find the appropriate means first to document then to translate physical reality into a proper tool that is manageable in computer language and applicable to an architectural one.

With reference to the Deleuzian discourse, it is accepted that the phenomena manifest themselves through multiplicities and the reality through complexities.[550] As regards, in this new conception of architectural production it is claimed that a single author's intervention could not be the appropriate methodology in determining and deriving the essentials of these multiplicities and complexities.[551] Since the multiplicity or complexity of reality is accepted to be unexplainable through one unifying theory, the strategy of contemporary practice is asserted to be one of recording/documenting the particularities, rather than searching for the underlying principles of generalities.[552] The particularities that belong to a

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[549] K. Michael Hays. "Architecture Theory, Media, and the Question of Audience" *Assemblage,* No. 27, Tulane Papers: The Politics of Contemporary Architectural Discourse, August, 1995, p. 43.

[550] This assertion is most made with reference to Deleuze's work "*A Thousand Plateaus,"* Gilles Deleuze and Felix Guattari. *A Thousand Plateaus: Capitalism and Schizophrenia*, Trans: Brian Massumi. Minneapolis: University of Minnesota Press, 1993, p. 141.

[551] Brian Massumi. "Sensing the Virtual, Building the Insensible," in Giuseppa Di Cristina (ed.) *Architecture and Science*, London: Willey-Academy, 2001, p. 198.

[552] Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997.

specific context, site, program or an external source than are put into function in non-linear, self-referential, and self-generative systems of organizations in order to create complex relationship of effects/forces which are then expected to result in novel, unpredictable and emergent products.[553]

Disregarding any difference between "natural" and "man-made" the noteworthy productivity and generativity of natural order that inherently possesses a mathematical organization and geometric structure, is then accepted as the main reference of architectural production. The geometric creativity and formal variety of natural forms are accepted as confirmations of the generative potential of a mathematical order that lies behind material organization and therefore started to be seen not only as the utmost source of formal creation but also as the departure point from historically loaded principles and norms of architecture. Mathematics in its present relation with architecture is claimed to serve neither as a guiding principle nor as a symbolic grounding platform.[554] However in claim of setting the principles of architectural process with a great transparency, mathematical relations are utilized as an automation agent of architectural production while mathematical methodology is put into practical use to produce novel results. Whereas the productivity of mathematical methodology is equated with emergent, inventive and divergent end results of formal production, its precision, certainty and abstractness are identified with efficiency and control, and gained a-signifying characteristics in the new conception of the architectural process.

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[553] Michael Weinstock. "Self-Organization and the Structural Dynamics of Plants," in *AD: Techniques and Technologies in Morphogenetic Design,* Helen Castle (ed.) Vol: 76, No: 2, p. 27.

[554] Zeynep Mennan. *An Interpretive Framework for Understanding Architectural Theory's self Representation*, Phd Thesis, Middle East Technical University, Department of Architecture, Ankara: 1997.

A materialistic approach that explains the particular formation/taking shape of an architectural object as the deliberate interaction of intrinsic generative forces takes the place of theories that see the final edifice as the necessary consequence of functional requirements or the essential interpretation of creative imagination.[555] As regards, within the appraised process of reification, the architectural edifice is started to be regarded as an object the utmost validity of which is confirmed by the data concretized in its very body.[556]

With respect to the discussions made throughout this study, the thesis tried to reveal the continuity in architecture's affiliation with mathematics, mathematical concepts and relations. In order to discuss elaborately what mathematical relations and numeric control that come with the use of digital technologies provide the contemporary architectural production with, a historical background has been briefly surveyed with reference to some central figures and to some essential turning points in the history of mathematics and science. The specific focus on some essential figures or periods either in mathematics or in science is due to their significance for the architectural theory and practice.

Concerning the historical background that this study outlined, it has been asserted that the role of mathematics in architectural production had shifted from a transcendental position to an ideal one. Although nineteenth century developments in mathematics and the emergence of non-euclidean geometries resulted in the instrumentalization of mathematical concepts and relations in the comprehension/exploration of the physical reality, it has been claimed that contemporary architecture's utilization of these developments marks an

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[555] R. E Somol. "Dummy Text, or the Diagrammatic Basis of Contemporary Architecture" in Peter Eisenman. *Diagram Diaries,* New York: Universe Publishing, 1999, p. 18-19.

[556] Ibid., p. 18-19.

instrumentalization process as the recent use of mathematical relations and numeric control is started to be conceived as just tools for productive and generative results.

The numeric control and the easy management of the architectural process or the productivity of digital technologies have made mathematics and numeric relations essential actors of architectural process in deriving the essential requirements of reality and in translating it to an architectural product. In that respect the thesis stated that contemporary architectures present a new definition in architecture's relation with mathematics in the determination of physical necessities, in the translation of these necessities to architectural edifice and in the controlling of the process.

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